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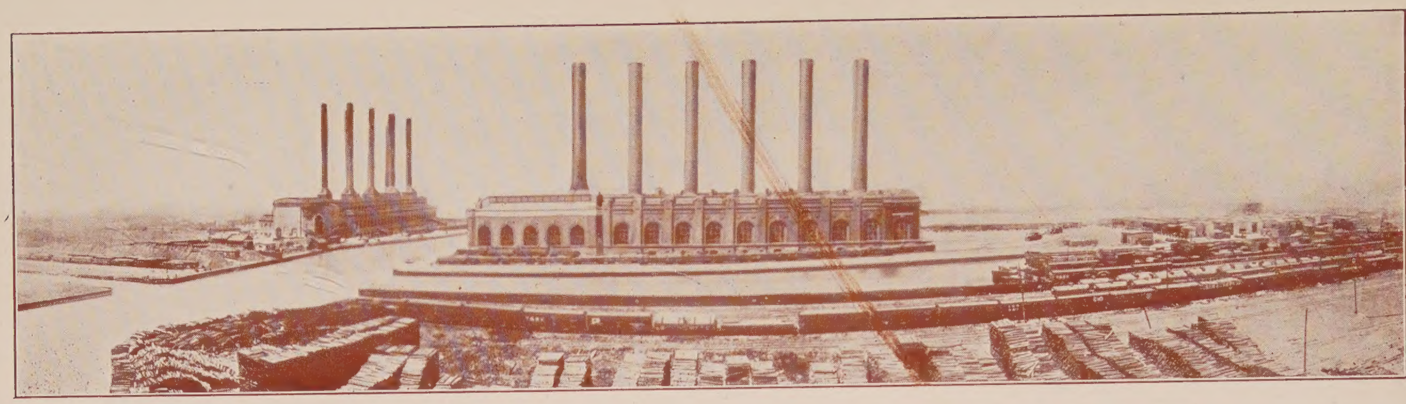


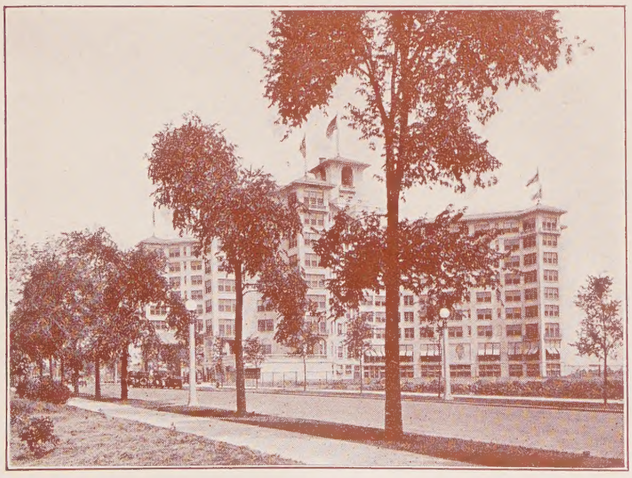
Quarry and Fisk Street Stations of the Commonwealth Edison Company, Chicago, Ill.

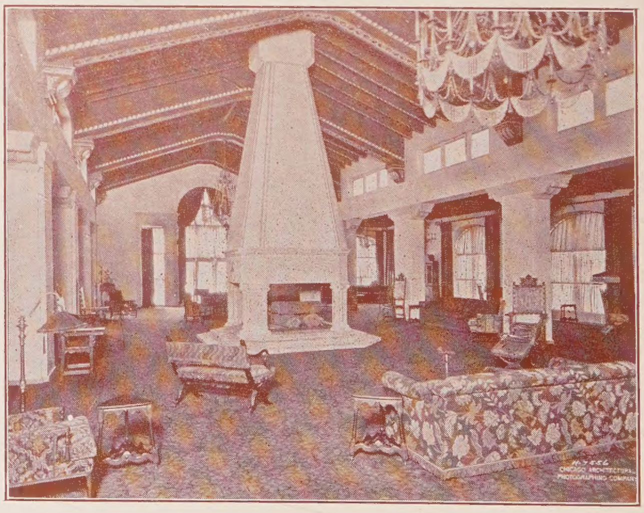
American Institute of Electrical Engineers
FORTIETH ANNUAL CONVENTION
Edgewater Beach Chicago, Ill.
JUNE 23-27, 1924

The central location of this convention and the timely importance of the technical program should insure a large attendance and unusual interest.

The scope of the technical program, printed elsewhere in this issue includes; electrical distribution, reactors, automatic stations, cables, street lighting, electrical communication, electrophysics, electrical machinery and standards.

As a leading center of electrical activity Chicago affords numerous opportunities for valuable inspection trips.





A. I. E. E. Annual Convention Headquarters
The Edgewater Beach Hotel, Chicago

JOURNAL

OF THE

American Institute of Electrical Engineers

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Vol. XLIII JUNE, 1924 Number 6

TABLE OF CONTENTS

Papers, Discussions, Reports, Etc.

Institute and Related Activities

American Institute of Electrical Engineers

COMING MEETINGS

Northeastern District Regional Meeting, Worcester, Mass., June 4-5

Annual Convention, Edgewater Beach, Chicago, Ill., June 23-27

Pacific Coast Convention, Pasadena, Cal., October 13-17

MEETINGS OF OTHER SOCIETIES

Society for the Promotion of Engineering Education, Boulder, Col., June 25-26

American Physical Society, Stanford University, Cal., June 25-28

American Association of Engineers, San Francisco, Cal., June 11-13.

American Society of Civil Engineers, Pasadena, Cal., June 16-20.

American Society for Testing Materials, Atlantic City, N. J., June 24-27.

Current Electrical Articles Published by Other Societies

Proc. American Railway Association, Signal Section, March, 1924

The Application of Alternating Current Supply with Battery Reserve to Signal Systems, by H. G. Morgan, pp. 698-704

Journal of American Welding Society, April, 1924

Reclamation of Cast Steel Car Castings by Arc Welding, by H. R. Pennington, pp. 28-35

Proc. of Institute of Radio Engineers, April, 1924

Formulas and Tables for the Calculation and Design of Single-layer Coils, by F. W. Grover, pp. 193-208

Short Period Variations in Radio Reception, by G. W. Pickard, pp. 119-158

New Applications of the Sodion Detector, by H. P. Donle, pp. 159-175

Physical Review, April, 1924

The Power Loss in Condensers with Liquid Dielectrics, by Louise S. McDowell, pp. 507-519

Journal of the A. I. E. E.

Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences

Vol. XLIII JUNE, 1924 Number 6

Decisions of the Publication Committee

At the last regular monthly meeting of the Publication Committee a number of important matters was discussed and acted upon, including technical committees' annual reports, the index of TRANSACTIONS, publication of authors' business affiliations, and the large amount of material received for publication. Definite action was taken on several of these subjects, as explained in the following items:

Technical Committee's Annual Reports

Several years ago the Board of Directors inaugurated the practise of requiring annual reports from each of the technical committees. It was intended that these reports should not only cover the actual activities of each of the several technical committees, but should also include a resumé of the state of the art in each technical committee's field. While some early reports did little more than point out the actual activities of the committee in Institute work, there has been noticeable improvement and broadening in the scope of these reports from year to year, so that many of of them are now of undoubted value in indicating the latest advances in various branches of electrical engineering. It is recognized now that these annual reports should be given as wide publicity as practicable, in order that the members of the Institute may keep informed regarding the state of the art in all branches of electrical engineering. For this reason, a large part of the first session of the Annual Convention will be devoted to the presentation of discussion of these reports. Advance copies of the reports will be available sometime before the date of presentation and in the future they will be published in full in the JOURNAL, if necessary running consecutively through several issues, as space permits.

Index of Transactions 1911-1921 Inclusive

As announced in the April issue of the JOURNAL, it is proposed to publish probably during the next year an index of the papers contained in the annual TRANSACTIONS of 1911 tô 1921, inclusive. An index has been published covering the years 1884-1910, inclusive, including both the synoptical and topical index, and there has been a wide demand for an index covering the period from 1911 to date. It was decided to include the years 1910-1921 in this index, for the reason that the size of the TRANSACTIONS was changed beginning with the year 1922 and any index following that date would naturally correspond with the size of the volumes indexed. The forthcoming index will therefore be printed in 6 by 9-inch size page, corresponding to the TRANSACTIONS for that period. A report to the Board of Directors, detailing the probable cost of the proposed publication and the procedure necessary to complete the work, was approved by the Board on May 16th.

Publication of Author's Business Affiliations

Several years ago the practise of printing the business affiliations of the authors of Institute papers at the beginning of each paper was inaugurated, for the purpose of informing readers in regard to the business connections and the professional standing of the authors. While there is no question that it is quite desirable to define the author's standing in the engineering field, the placing of his business connections at the head of each paper has been objected to, on the ground that it tends to commercialize the Institute to some extent, and has conveyed the impression in some instances that the paper was a company production rather than the work of the individual author. At one of its recent meetings, the Meetings and Papers Committee passed a resolution, recommending that the business affiliations of authors be placed in the form of a footnote at the bottom of the first page of the paper and not directly under the author's name at the top of the page, as is now the custom in the JOURNAL. This recommendation has been submitted to the Publication Committee, which is in sympathy with the idea. No final decision, however, has been made in regard to this. It is desirable that no form of typographical alterations be made in published papers during a volume year. If the business connections are to be transferred from the beginning of the article to a less conspicuous place, the change will be made beginning with the January, 1925 issue of the JOURNAL.

Publication of the author's grade of membership will be continued as heretofore and in view of the fact that papers cannot be received from non-members of the Institute, except by special permission of the Board of Directors, the authors of such papers will hereafter be designated by the term "non-member."

Increase in Material Received for Publication

The Publication Committee is confronted this year with certain perplexing problems which have arisen through the unusually large production of technical papers received for publication in the JOURNAL and in the TRANSACTIONS. The large increase in the number of papers prepared by engineer writers indicates a commendable and healthy activity in Institute affairs by members. A problem is to accommodate these papers to the best possible advantage with the funds available for publication purposes.

In April of this year, there was in hand a sufficient amount of material for publication to fill the pages of the JOURNAL during the remainder of the calendar year, this not including the papers under way for the Annual and the Pacific Coast Conventions this summer. In addition to the technical papers presented at meetings, there were in hand in May 200 pages of "contributed" matter which had been accepted for publication in the JOURNAL. The situation may be plain when it is stated that the present appropriation for publication provides for 350 JOURNAL pages of technical papers during the balance of the year, while there is on hand material equivalent to 465 pages, plus an estimated 455 pages forthcoming from the two early conventions; or 570 pages in excess of what the funds appropriated will pay for. The number of pages that can be printed in a single issue of the JOURNAL is limited by the publication appropriation made each year. The Board of Directors each year has increased the publication appropriation, but it is obvious that Institute income will not permit of further material increases for this purpose. For the balance of the year, therefore, the papers selected for publication in full will be those which tell their story with a minimum of words.

Some Leaders of the A. I. E. E.

EDWARD WESTON, fourth president of the A. I. E. E., was born in Shropshire, England, May 9, 1850. He holds the degrees of Honorary LL. D., McGill University, 1903; Sc. D., Stevens Institute of Technology, 1904, and Princeton University 1910.

Dr. Weston came to the United States in the year 1870, shortly afterwards becoming chemist and electrician for the American Nickel Plating Company. In 1873 he prepared the first of the copper-coated carbon electrodes, later universally used. In 1875 he became a partner in the firm of Stevens, Roberts and Havell, manufacturers of direct-current generators. In the year 1881 this business, then known as The Weston Company, was consolidated with the United States Electric Light Company, with which company Mr. Weston continued as electrician until the year 1888.

Since 1888, Dr. Weston has devoted his time and talents to original research and invention of electric measuring instruments. He was vice-president and general manager of the Weston Electric Instrument Company from 1888 until 1905; since the latter year serving as President of the Company, and has been an outstanding leader in the developments and manufacture of electric measuring instruments of precision.

In February of this year at the dedication of the Moore School of Electrical Engineering in Philadelphia, Dr. Weston received the honorary degree of Doctor of Laws, in recognition of his distinguished services to the world.

He was president of the A. I. E. E. for the annual term 1888-89.

A. E. C. Committee Report on Muscle Shoals

At the request of Senator Norris, Chairman of the Senate Committee on Agriculture, the American Engineering Council appointed a committee to consider the disposition of Muscle Shoals. The committee consisted of Fred R. Low, Harold W. Buck, Leonard Waldo, H. E. Howe, E. B. Whitman, J. B. Davison, and H. B. Walker. In its report to Senator Norris the committee states that the time was too short to sift out from the conflicting data a sound engineering recommendation as to the disposition or use of the property. The committee was however in unanimous agreement on the following points:

"First, that a Joint Committee of Congress should be constituted 'to consider offers, conduct negotiations and report definite recommendations' as advised by the President in his message to Congress delivered December 6, 1923.

"Second, that no disposal should be made of any of the Muscle Shoals properties or rights until each Joint Committee of Congress shall have rendered its report.

"Third, that in no event should any disposition of the power plant be made that is not in substantial accord with the provisions of the Federal Water Power Act.

"In the course of its investigations the committee found nothing to justify the popular belief that the operation of the existing plants at Muscle Shoals will make substantially cheaper fertilizers immediately available, inasmuch as nitrates, however important, constitute but one of the three basic ingredients of commercial fertilizers, and consequently a considerable reduction in the nitrate cost would be reflected only to a slight degree in the cost of the marketable product.

"The committee further found that recent developments of the synthetic process of nitrogen fixation had materially changed the entire outlook in the art and it is now quite possible that this process, for the use of which the so far unsuccessful Muscle Shoals Plant No. 1 was designed, may yet yield nitrate at a cost to compete with that obtained from Chile; and Plant No. 1, until recently considered a failure, may be the more valuable of the two constructed by the Government."

Some Notes on Street Lighting

BY PRESTON S. MILLAR
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Review of the Subject.—*This paper, after discussing the criterion of street lighting effectiveness, presents comments upon certain of the variables of street lighting.*

Test data are presented upon certain sizes and types of incandescent lamps for street lighting. An attempt is made to indicate something of the present status of street lighting, including the presentation of a selected list of modern lamp posts and lighting equipments. The paper concludes with data to show the character of installations now recommended by experts for the lighting of various classes of streets, and the advance in recent years in ideas of desirable levels of street illumination.

* * * * *

A GOOD way to begin any activity is to define the purpose in view. The purposes of street lighting have been defined variously. Starting thus from different premises, writers on the subject have naturally arrived at divergent conclusions. In consequence there is uncertainty as to the principles which should guide in the design of street illumination.

The Purposes of Street Lighting. Reduced to lowest terms it is believed that the purposes of street illumination are:—first to reveal, and second to embellish.

Protection against the hazard of criminal violence and collision; security in avoiding obstacles and inequalities in roadway; facility in finding one's way about, all require that the light which is provided shall reveal what it is important to see on or about the street. No system of street lighting is effective which fails to achieve this purpose. Any system of street lighting is effective largely in proportion as it serves this purpose.

Of secondary importance, to be weighed with respect to the type of street involved, is the extent to which a street lighting system, by reason of the design and location of lamp supports and equipment, promotes the good appearance of the street in the daytime, and by virtue of these things and its characteristic of light distribution, promotes the good appearance of the street at night.

Subsidiary purposes which street lighting systems have been designed to serve are advertising of the locality, attracting trade, etc. These more properly fall in the category of advertising display, but are sometimes combined with street lighting for reasons of expediency.

Among diverse requirements for a successful street lighting system which have been put forward, the following may be noted:

"The problem of street illumination is to produce a uniform low intensity."

* * * * "I recognize that a moderate diversity (of illumination) is much more satisfactory."

* * * * "Avoidance of glare is the most important factor in street lighting."

It is submitted that any of these and other alleged major requirements to be served by street lighting may be tested fairly by ascertaining to what extent they contribute to the revealing power of the street lighting system and to the embellishment of the street. It would perhaps be desirable to sacrifice other features to secure a "uniform low intensity" if by doing so the revealing power of the lighting would be greater, but until such has been demonstrated to be the case, the writer for one is unwilling to subscribe to this statement. The test of whether uniform distribution of light along the street or a "moderate diversity" is better lies in a determination of revealing power of the two kinds of lighting. That "avoidance of glare" is not the "most important factor" is evidenced by the obvious fact that this can be accomplished by extinguishing street lamps, which would not at all contribute to the revealing power of the lighting system.

In this country the history of the street lighting art records the prevalence for a period of years of first the "2000 candlepower" criterion and subsequently the candlepower delivered 10 deg. below the horizontal as measures of street lighting effectiveness. The causes contributing to the adoption of these two criteria are now well understood. Neither could have come into use had revealing power been recognized as the principal test of street lighting.

Effectiveness in Street Lighting

There is at this time no generally accepted criterion of effectiveness in street lighting. It is customary to decide between competing street lighting systems by any means which best commend themselves to those responsible and to stipulate in contracts the lamps, equipment and service which together constitute the street lighting system. Among the means availed of in choosing a system are usually inspection, observation, and tests of the lighting units in a laboratory or on the street or both. Actual attempts to determine relative revealing power of various systems are rarely if ever, made in practise.

Effectiveness in a street lighting system like personal charm is recognized when encountered, but is difficult to define. It depends upon the right combination of several qualities, some of which are perhaps intangible. However, when a street lighting system attains to thorough effectiveness, the illuminants will be found to be located and spaced suitably, to be mounted at a

To be presented at the Annual Convention of the A. I. E. E., Edgewater Beach, Chicago, Ill., June 23-27, 1924.

desirable height and to be enclosed or equipped in such a way as to present to the eye a desirable combination of candlepower and brightness for the lighting unit and of distribution of light along the street and upon buildings. Suitability and desirability in these particulars sometimes hinge upon the local conditions peculiar to the installations. A few comments of general applicability may, however, be in order at this point of the discussion.

Location of Lamps. For effectiveness in illuminating streets there is no location quite so favorable as directly over the driveway. Where the lamps are few and far between and of small size, and where the pavement is of asphalt or other material which tends to take a polish from motor traffic, the advantages of locating the lamps over the driveway are greatest. Thus guy wire suspension and mast arm post mountings possess advantage in such installations. When the lamps are numerous and of large size, and the street illumination is of higher intensity, precise location of the lamps is of less importance since the greatest revealing effectiveness does not have to be obtained from them. This point is well illustrated in Fig. 1 in which a modern twin lamp installation supersedes an earlier mast arm installation. The new installation is effective in spite of a location which makes for much lower effectiveness per unit of light. When a relatively great amount of light is produced, effectiveness of utilization may be sacrificed somewhat to secure improved appearance. With the lesser quantity of light afforded by the earlier installation, the location of lamps over the street was essential in order to utilize with fair efficiency the relatively small amount of light which was produced.

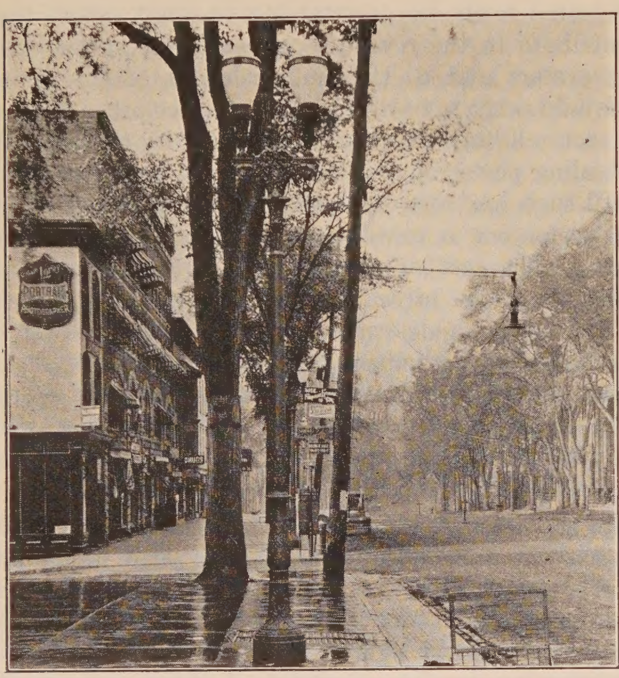

Fig. 1

In the old system, but little light being available, the lamps were located over the roadway for greatest effectiveness. The more adequate modern lighting permits location of lamps for pleasing effect.

Spacing of Lamps. Evidently spacing intervals should be small enough to avoid dark areas between lamps. On the other hand, the writer's experience has indicated that it is not desirable to incur large expense through reducing spacing intervals in an attempt to approximate uniformity of illumination along the street. Discernment in the street at night is largely dependent on contrasts of light and shadow. Studies of revealing power made for the joint street lighting committees of the National Electric Light Association and the Association of Edison Illuminating Companies 1914-1915, indicated that when uniformity is attained through multiplicity of small illuminants, contrasts are diminished through the elimination or reduction of shadows, so that objects on the street and depressions or holes in the street surface are not seen so well as they are when lighted from fewer, larger lamps. These, through failing to provide uniformity of illumination, do produce relatively strong shadows which are an aid to visibility.

Mounting Height. In connection with the control of light for street lighting purposes, much planning and design have been influenced by a desire to approximate uniformity of illumination along the street. Attention in this connection has been focused upon illumination intensity curves such as those shown in Fig. 2. Other aspects of street lighting effectiveness have sometimes been sacrificed to secure a considerable percentage increase, but a small absolute increase in illumination midway between lamps. Such improvement in midpoint illumination can be had, of course, only at the expense of largely increased candlepower just below the horizontal. To avoid glare as a consequence of such light distribution, the units have sometimes been mounted high. The resultant effect upon the illumination curve has been thought to be good.

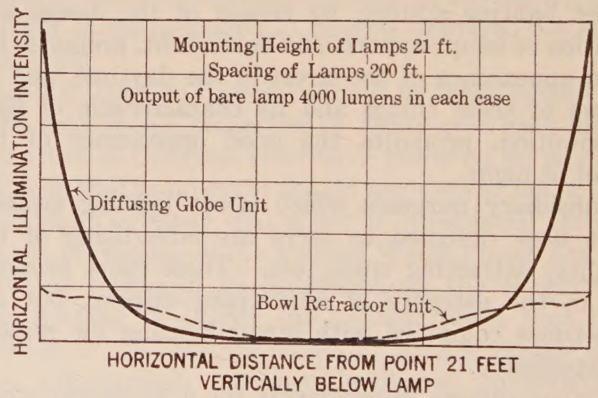

Fig. 2

The desire to approach uniformity of illumination along the street has influenced street lighting design quite generally.

It must not be forgotten, however, that as lamps of symmetrical horizontal distribution are mounted higher, the proportion of light flux delivered upon the street

surface is diminished. This effect is increased if the candlepower just below the horizontal is made large to reinforce the illumination midway between lamps. In Fig. 3 curves are shown to illustrate the relations that are here involved. Considering the total light produced, a smaller part is delivered below the horizontal from a diffusing globe unit than from a bowl refractor. With low mountings of the bowl refractor, the advantage in the proportion of light delivered upon the street is quite large. At 43 ft. mounting height, which, of course, is higher than may be considered practicable when lamp posts are employed, the proportion of light delivered upon the street is the same for the two types of distribution. If, however, some light is desired above the horizontal, and the lower hemispherical light flux alone is considered in this relationship, the relative proportions delivered upon the street surface are shown in the two lower curves,

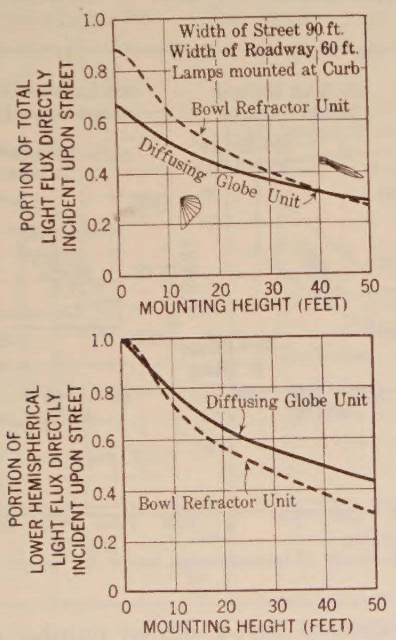

Fig. 3

With increased mounting heights, the proportion of light flux delivered directly to the street surface becomes smaller.

the bowl refractor delivering a smaller proportion of flux from all practicable mounting heights.

This consideration apparently has entered into the design of two-way and four-way refractors, described later, which are intended to deliver larger proportions of the light along the streets by utilizing the light which otherwise in some installations would be wasted or used to poor advantage in other directions.

Characteristics of Equipment and Illumination. The avoidance of undue glare is important to street lighting effectiveness. Glare depends largely upon the brightness and candlepower of the lighting unit within the field of vision and is modified by the brightness and extent of other illuminated areas likewise within the field of vision. It is modified also as the source is removed from the center of the field of vision.

The relationship between candlepower and brightness of source, and the relationship of these to location and background in street lighting are not well understood. The writer has been unable to accept the indications of his own and other attempts to measure and evaluate such effects. In none of them has the subjective element been eliminated or brought under adequate control. No way has been found to reproduce for test purposes the conditions of attention which obtain in the ordinary use of the street by drivers and pedestrians, nor have means been found to evaluate the feeling of satisfaction and contentment with one lighting system which may not be experienced with another lighting system, when the latter cannot be said to produce serious glare which can be measured in visual tests, but is still unsatisfactory as to brightness or candlepower in the direction of the eye. Considerable pioneer work has been done along these lines and street lighting systems have been designed with reference to the results of such investigations. The writer's experience in the conduct of investigations in this field and his observation of designs, based upon such investigations, lead him to feel that the answer has not been found by such means.

The problem resolves itself in the main, into a means of delivering sufficient light upon a street without producing serious glare. The usual means employed are to mount illuminants at a moderate height and employ sufficiently large globes to keep the brightness below the point which produces serious glare, or else to mount the lamps high with a view to removing them from the center of the field of vision, employing some means of directing the light downward upon the street.

An interesting comparison of these two methods has been afforded through demonstration installations in Columbus, Ohio during the spring of 1924. These installations have covered too short a length of street to make the demonstrations entirely convincing, but the contrast between the two systems was displayed in so striking a fashion as to occasion surprise that, after years of effort along the lines of improvement in street lighting, leaders in the art could entertain such diverse views as to means of accomplishing the desired ends.

One more comment on the desirability of uniformity in street illumination should be made. When lamps of moderate or large size are mounted at relatively large spacing intervals, the only way to approach uniformity of lighting is to redirect the light along the street with a large excess at angles slightly below the horizontal, in order to deliver enough light midway between lamps to render the illumination in such areas comparable with that nearer the lamps. This can be accomplished only at the expense of such high candlepower and brightness at angles slightly below the horizontal as to occasion serious glare at any practicable mounting heights. The superiority of substantially uniform illumination along the street over a moderate

diversity, resulting from more natural light distribution characteristics, is usually insufficient to compensate for the attendant condition of glare.

Uniform illumination of moonlight is excellent. But uniform illumination achieved by many small illuminants staggered along both curbs or by means of candlepower distribution curves, having an excess just below the horizontal, imposes damaging visual handicaps and, in the writer's opinion, is not be to desired. Observation and experience indicate that in street lighting moderation is generally desirable. Moderate size lamps, equipped so as to modify light distribution somewhat in the direction of uniformity of illumination, moderately bright, moderately spaced and at moderate heights, lend themselves to successful street illumination in the generality of cases. Departures toward either extreme in any particular may be justifiable and may be desirable, but in general, moderation is the best rule of practise.

It appears to be indicated that in proportion as little light is available for streets, it is important to employ equipment which is designed to direct it along the street to the exclusion of the side of the street. Conversely, when ample light is available, unnatural and dissymmetrical light distributions become unnecessary and buildings along the street may be lighted as well as the street surface with advantage to visibility conditions and to the appearance of the street.

In the interesting and useful demonstration of street lighting systems made available last winter, through the co-operation of the National Lamp Works of the General Electric Company, The Cleveland Electric Illuminating Company and the Cleveland Municipal Department of Light and Heat, comparison was made between lamps of a given size, spaced at equal intervals but mounted at respectively 16½, 21 and 26 ft. above the street level, the highest mounting being out over the street and the lowest mounting being over the curb. The lowest mounting resulted in the greatest amount of light being delivered upon the street with some appreciable glare. The highest mounting resulted in a smaller quantity of light being delivered upon the street and less glare. The writer's independent judgment favored the medium mounting height as producing the largest effectiveness under the particular conditions which prevailed, and he was advised subsequently that this judgment tallied with that of most observers. This verdict was applicable, of course, only to the particular conditions of these trial installations. But the incident illustrates the fact that the most desirable mounting height in any case can best be determined by trial in the street.

Some years ago in New York City, in order to ascertain the best location and arrangement of lamps for lighting a boulevard, lamp posts were mounted in rock ballasted barrels which were shifted about to secure best practicable locations. The result was excellent utilization of the light from the lamps. Some such method of experiment in the street is to be recommended wherever it is practicable to apply it.

Illuminants

Rating Accuracy of Tungsten Filament Lamps. Like all illuminants which are employed in street lighting, tungsten filament lamps differ individually in light output and efficiency when new, and vary somewhat as they are operated. It is not possible to present any tests of rating or of life performance which may be regarded as representative of all tungsten lamp products or of any one product at all times. In Figs. 4 and 5, however, there are shown ratings and life performance data of Mazda lamps of the street series and multiple types which are perhaps as nearly representative as any that might be chosen.

The tests of rating represented in Fig. 4 in the form of target diagrams bring together samples of various Mazda products selected over a number of months.

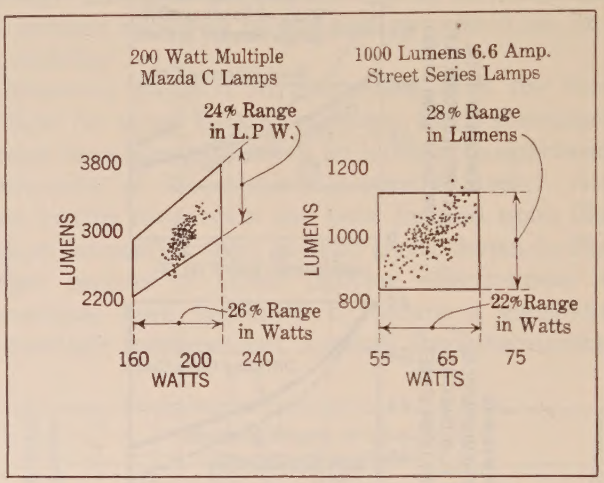

Fig. 4

Rating accuracy of incandescent lamps for street lighting.

It is to be expected that a similar number of lamps of some one product produced at one time would display somewhat more consistency than is here shown, but such a group would be less representative than the group chosen. The trapezoid and the rectangle represent the tolerances of standard lamp specifications, and each dot indicates by its location on the diagram the lumens and watts of a lamp. In the sample ratings illustrated, a range of ±14 per cent in lumens for series lamps and of ±12 per cent in lumens per watt for multiple lamps is indicated for new lamps by the standard specification tolerances.

It is understood that there are in existence some street lighting specifications which call for closer conformity to rated lumens on the part of individual lamps than has been attained by the most progressive lamp manufacturers. Such provisions, if complied with, occasion undue expense in the selection of lamps and accomplish little, if anything, of advantage to the public. If not complied with, they introduce possi-

bilities of trouble which are undesirable from every point of view. It is submitted that street lighting specifications ought not to prescribe closer adherence to rating on the part of the illuminants than best practise permits, unless it is understood that such closer adherence involves increased cost which must be met at public expense.

Laboratory performance throughout life with respect to light output and efficiency is indicated in Fig. 5 for samples of series and multiple Mazda lamps of the type illustrated.[1] These performance characteristics are perhaps as representative as any that might be chosen. The performance characteristics of other sizes, types and makes of lamps may be materially different from those illustrated. The better lumen maintenance of the series lamps as compared with the multiple lamps is the natural result of the increased watts expended in the lamp as the filament resistance increases throughout life. The lumen maintenance of the multiple lamp, though not so good as that of the

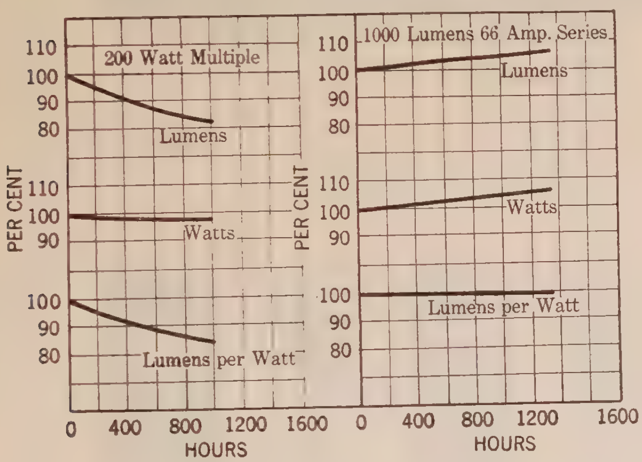

Fig. 5

Life performance of certain sizes of incandescent lamps for street lighting.

series lamp, is excellent as compared with earlier types of incandescent lamps.

These changes in light output throughout the lives of lamps do not take into account losses due to dust or discoloration of reflectors or globes.

No statistics are available to the writer to show the change in light output of modern magnetite arc lamps throughout the period of electrode life and between cleaning and trim periods.

Multiple Lamps. With the development of a successful system of remote control[2] and of reliable time switches, the multiple incandescent lamp operated from commercial service mains has come into much greater favor than it formerly enjoyed for street lighting purposes.

1. Lamp test statistics are available through the courtesy of the Lamp Committee of the Association of Edison Illuminating Companies.

2. Remote Control of Multiple Street Lighting—W. T. Dempsey, Journal A. I. E. E., October 1923, page 1106.

Arc Lamps. The arc lamp has now been very largely superseded by the incandescent lamp for utilitarian lighting of secondary streets. In its more powerful form, however, employed with diffusing globes, the magnetite lamp is a very lively factor in lighting the most important and distinctive streets of many cities.

Present Status of Street Lighting in This Country

Municipal Expenditures. Cities ordinarily spend about 75 cents per capita per annum for street lighting. It seems to be the general feeling of those, who after study of the subject have expressed themselves in the technical literature, that about twice this amount should be spent on the average for street lighting, in order to provide illumination which is adequate to meet the requirements of modern congestion of high speed traffic. Differences in local conditions may double or halve the sum required in a given community to afford street lighting of the desired effectiveness.

Unity of Design. Street lighting systems in most American cities suffer from lack of uniformity and style, having been designed at different times by people whose ideas as to the requirements differed. For the most part, systems have grown from small beginnings, according to the seeming expediency of the hour and without any coherent principle as a basis upon which to develop a homogeneous system expressive of the city's character and reflecting favorably upon its management. Few, indeed, of the larger cities have attempted, as St. Louis is now doing, to introduce an entirely new street lighting system designed with unity of purpose to serve present needs and to be capable of expansion for future requirements without sacrifice of unity of design.

Lamp Posts. In lamp mountings, independent posts for one or more lamps or brackets on trolley line poles are in general use. The cluster of five lamps, more or less, in diffusing globes mounted low is passé. The columnar post for one lamp, the bracket post for lantern type of housing, and the modern multiple lamp post are illustrated by a variety of samples in Figs. 6 and 7. The inclusion of transformers in the bases of lamp posts has had an undesirable influence in making the diameter larger than is consonant with the purpose of the post, often robbing it of grace. In this respect, the posts for multiple lamps have possessed an advantage. Recent transformer types of smaller dimensions have mitigated this difficulty.

To a considerable extent the leading manufacturers of lamp posts, lamps and lamp equipment have influenced the type of street lighting installations, particularly in the smaller cities. For the most part, new street lighting systems which have been installed have been superior to existing systems. In street lighting the tendency to passing styles has not exceeded the bounds of moderation because innovations have had to justify themselves in the eyes of the purchasers

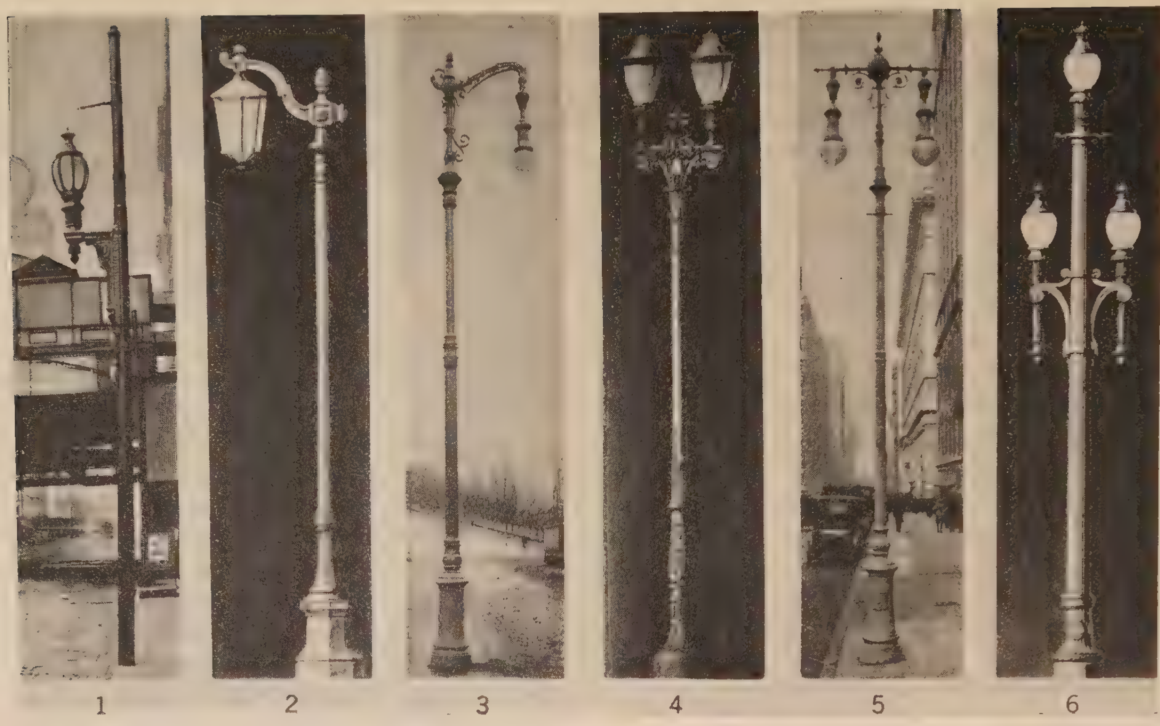

Fig. 6—Modern Street Lamp Posts

1. Chicago bracket on trolley wire post
2. Cleveland bracket
3. New York bracket
4. Saratoga twin lamp post with large and small alternate lamps in each globe
5. New York twin lamp post
6. Salt Lake City triple lamp post

Fig. 7—Designs Exhibiting Modern Tendencies in Street Lamp Posts and Equipment. These Illustrations are not Adjusted to a Common Scale.

1. Prismatic refractor globe
2. Prismatic bowl as used in Milwaukee
3. Diffusing globe as used in Saratoga
4. Diffusing panels enclosing reflector and dome refractor
5. Prismatic glass panels as proposed for St. Louis
6. Stippled glass panels enclosing dome refractor as used in Cleveland
7. Diffusing glass globe enclosing dome or bi-lux refractor
8. Rippled glass globe with or without interior refractor as used with magnetite lamp.

and users who have generally inquired rather carefully into their merits before committing themselves to the large expenditures involved.

Atmosphere and Tradition in Street Lighting

Economy dictates, at least for smaller installations, the choice of standard lamp posts and equipments. Such choice, however, loses distinctive qualities for the installation. There are some communities which are perhaps so characterless and colorless as to possess no traditions and to afford to the observer no distinctive features. When, however, a community is of distinctive character, it would seem that lamp post and lamp equipment design afford an excellent opportunity for the exhibition of atmosphere and traditions which ought to be availed of where practicable. Two illustrative installations occur in this connection. Some of the street lighting of Riverside, California was until recently provided from concrete posts the heads of which represented the archway of a Mission belfry, while a bell-shaped lamp shade represented the Mission Bell, the whole embodying the romantic Mission traditions of the neighborhood. Another instance is offered by the historic lighting of Independence Square, Philadelphia, in which the modern lamp posts and lanterns are designed to preserve the traditions through faithful reproduction of the oil lamp lighting of the Square which is said to have been designed by Benjamin Franklin. In neither case did the lighting achieve high effectiveness from the point of view of utilitarian street lighting. Both designs, however, are notable as worthy attempts at preservation of traditions in street lighting design and as illustrations of attempts to obtain a logically distinctive lighting system.

Lamp Equipments. Perhaps no phase of the street lighting problem is mooted so generally as is the question of equipment of the lamps. Preference for urban street lighting ranges from a diffusing ball, largely lacking in directive qualities, to optical equipments which afford maximum opportunity for directing the light as desired. Among intermediate equipments some combination of a slightly diffusing outer globe of large area with an internal refractor appears to meet with rather general approval. These combine a measure of control of the light with a reduction in brightness, achieving a satisfactory degree of effectiveness for many street lighting purposes. Lighting equipments of these types are illustrated in Fig. 8.

Notable advances have been made in recent years in the adaptation of prismatic glassware to street lighting. The prismatic refractor as a complete globe for street lighting units has proved very effective in redirecting light as desired. In its original form, limited apparently by cost considerations to relatively small size, its brightness was rather high and, in particular when used with the larger lamps, was too high for many purposes. A more recent development of the refractor in a larger size (16¾ in. upright inverted) has mitigated this difficulty.

More recently the prismatic refractor has found an interesting field of usefulness as an internal directing element of a street lighting fixture employed with a larger outer globe, usually more or less diffusive in character. Such directing refractors employ horizontal prisms to direct the light upward or downward, or vertical prisms to direct the light along the street, diverting it from the side of the street. Some illustrations of refractors employed in this way appear in Fig. 8.

Another recent development of the refractor, which is designed to form a complete lighting equipment,

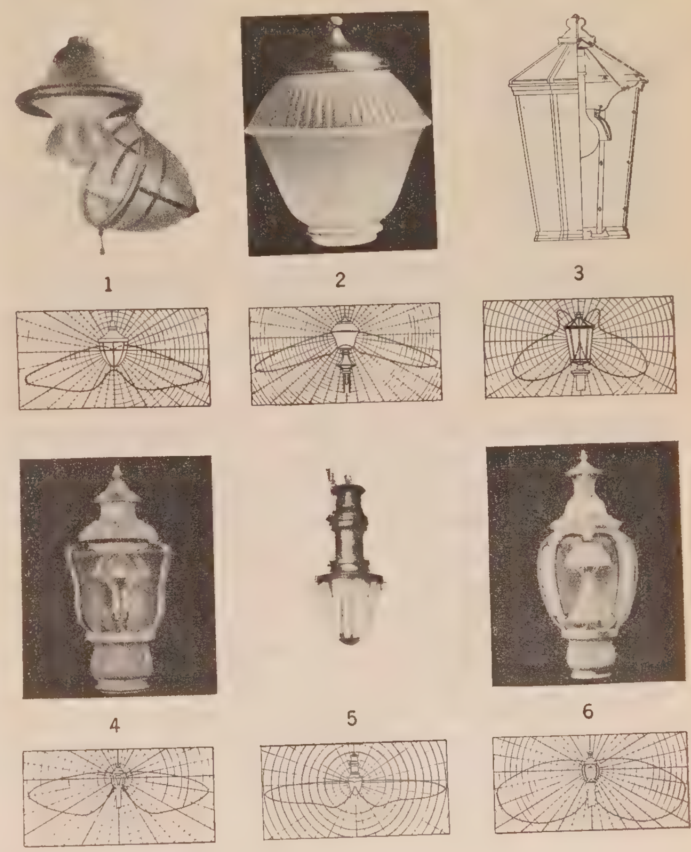

Fig. 8—Prismatic Glass for Light Control

1. Equipment used at East Cleveland
2. Refractor post top
3. Lantern as used at Cleveland
4. Stippled glass globe with dome refractor
5. Magnetite lamp with inner refractor
6. Panelled stippled glass globe with dome refractor and reflector.

employs a system of prisms, designed to direct much of the light in two directions up and down the street, or in four directions at rectangular street intersections. The horizontal distribution of candlepower for such refractors shows either two or four pronounced lobes. Where accurate setting of such equipment can be assured, and where the high brightness is not objectionable, these two and four-way refractors may be found useful. They are intended to be applied chiefly in "ornamental" lighting systems; *i. e.*, with underground distribution and ornate posts and housings.

Still another application of prismatic glassware is in

the form of panels of a lantern type of street units as illustrated in Fig. 7.

Highway Lighting Units

A feature of modern development in street lighting is the lighting of highways. This is very desirable as a contribution toward the construction of pole lines in rural communities and toward the solution of the difficult automobile headlighting problem, in addition to the direct advantages of street lighting which apply to highways as well as to city streets. In the lighting of highways spacing intervals must of necessity be great and the design of equipment must be such as to

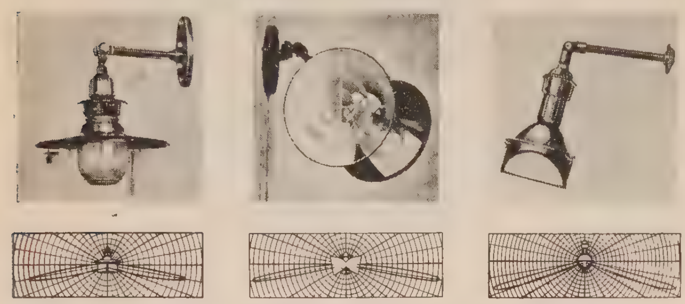

Fig. 9—Highway Lighting Units

utilize to the utmost the available light flux for delivery along a narrow strip of highway. A concentration of light up and down the road with a generous flux of light on the street below the lamp is indicated. Although some attempts in this direction were made at an earlier date, highway units were not put forward actively until the availability of the concentrated filament, gas-filled tungsten lamp made possible higher effectiveness from such devices than was formerly attainable. Three designs, with practically the same objects in view, are illustrated in Fig. 9. All accomplish more or less well the purpose of delivering the light along the highway. None is conspicuous for grace or beauty. In highway lighting units, "handsome is as handsome does."

Standards of Illumination for Various Classes of Streets

Several writers[3] on street lighting recently have classified streets and suggested ranges of illumination suitable for each. In Table I an attempt is made to combine these statements to indicate modern ideas of suitable levels of illumination. Obviously, in consolidating them certain liberties have had to be taken. The table, however, is probably fairly representative of their views as expressed. For each class of street, the range of lower limits and the range of upper limits have been shown for each particular of street lighting which has been covered by these writers.

In relating lamp lumens to illumination on the street surface, it is necessary to take into account the loss of light in the lamp equipment, the width of the street, the location and height of the lighting unit and the reflection of light from buildings.

Advancing Standards of Street Illumination

Increase in high-speed vehicular traffic and growing appreciation of the importance and value of good street lighting have brought about a rapid advance in levels of illumination advocated for street lighting. A good illustration is afforded by the comparison in Table II between illumination intensities regarded as typical of

3. C. W. Koiner, Chairman Commission on Street Lighting, Society for Municipal Improvements, *Elec. World*, Dec. 23, 1922.
Engineer Commissioner—District of Columbia, Letter, 3/25/1924
A. F. Dickerson, General Electric Company, *Elec. World*, 7/22/22.
R. E. Greiner, Edison Lamp Works, *Bulletin L. D.* 144.
E. A. Anderson, National Lamp Works, *Bulletin No. 46*.
N. E. L. A. Street & Highway Lighting Division, 1922.

TABLE I
RECOMMENDED STANDARDS FOR STREET LIGHTING

	Class of Street	Cp. per Unit	Mounting Height (Feet)	Spacing (Feet)	Lamp Lumens per Linear Foot of Street
Range of lower limits	Primary Business	600—1000	14—18	60—100	100—330
" "upper "		2500—5000	25	150	250—1000
Range of lower limits	Secondary Business	600—1000	14—15	80—100	50—150
" "upper "		1000—2500	16—25	125	160—500
Range of lower limits	Outlying Business	250	12	60—80	20—125
" "upper "		600	16	80—125	100—200
Range of lower limits	Wholesale and manufacturing district	250—400	20	125—150	20—50
" "upper "		1000—1500	25—30	250—300	50—100
Range of lower limits	Thoroughfares	250—400	15—20	75—150	10—100
" "upper "		600—1500	25—30	200—300	30—125
Range of lower limits	Residential	100—250	10—14	100—150	6—40
" "upper "		600	20—25	250—350	8—50
Range of lower limits	Boulevards	250—400	12—15	100—125	10—60
" "upper "		600—1000	20—25	200—300	30—80
Range of lower limits	Parks	250	12—14	100—125	10—40
" "upper "		600—1000	20—25	200—300	30—50
Range of lower limits	Outlying districts, alleys and side streets	100	14—15	100—200	2.5—10
" "upper "		250—600	18—20	250—400	5—50
Range of lower limits	Highways	250	25—30	250—300	4—8
" "upper "		400	35	400—600	8—12.5

TABLE II

ADVANCING IDEAS OF SUITABLE LEVELS OF STREET ILLUMINATION

1916 Standards			1924 St. Louis Proposal	
Class of Streets	Avg. Horiz. Illumination Intensity	Desirable Characteristic	Zone	Average Ft.-candles
Important avenues and heavy traffic streets	0.5-1.0 ft. c.	Ample light on building	Downtown retail	1.68 ft. c.
			Intermediate Zone 1	1.20
Secondary business streets	0.1-0.2	Ample light on building	Intermediate Zone 2	0.7
			Intermediate Zone 3	0.47
			Major thoroughfares outside central zones	0.30
City residence streets	0.05-0.1	Subdued light on bldg. fronts	Residential heavy traffic	0.16
Suburban highways	0.02-0.04	Max. light on roadway		
Suburban residence streets	0.005-0.02	Very subdued light on building fronts	Residential outlying	0.09

practise in 1916[4], and levels of illumination intensity proposed for the new lighting of the streets of St. Louis.[5] The St. Louis proposed illumination levels are considerably in advance of the standards advocated in Table I. The writer does not know how representative they are of modern ideas, but if they are no more than the expression of convictions reached by municipal authorities after investigation, the contrast which they form with the levels regarded as typical in 1916 is a striking commentary on the advance of street lighting theory if not of practise.

It is not clear at this time how far this advance in standards of street lighting will be carried, but it is clear that large advances are being made with results that are beneficial to the public, the utility company and the manufacturer of equipment.

The author desires to thank representatives of the General Electric Company, the Holophane Glass Company and the Westinghouse Electric and Manufacturing Company for street lighting information supplied upon request, and to express appreciation to several others who have assisted in the preparation of this paper.

THE LAMP HAS SET A CHALLENGE

There is an aspect to this reduction in the price of lamps other than the resulting lower cost to the consumer. This aspect is what the reduction signified as a manufacturing accomplishment—it acts as a challenge in the manufacture of other electrical products. What Henry Ford has demonstrated to the automobile industry the larger incandescent lamp factories have demonstrated no less conclusively to the electrical industry. Both cases involve the fundamental economic principle that improved machinery and processes, under favorable conditions made possible by mass production, may offset the great increase which has come in the cost of both labor and materials and reduce the cost of the product to the consuming public. Such an operation it is that has brought the automobile into the almost universal service of the masses. It has caused this reduction of the price of lamps to an average 30 per cent below the pre-war level, in spite of the fact that the cost of labor in the lamp factories has doubled and the cost of materials more than doubled in the period. Improved lamp-making machinery has so cut the labor cost per unit and economized on factory space as actually to result in a marked saving to the consumer. Meanwhile, there are two and a half times as many incandescent lamps in use as there were ten years ago. How much of this increased consumption has been induced by falling prices, of course, can only be conjectured.

It is a notable achievement in industrial history that is worth the serious consideration of every other manufacturer in the electrical industry. How far can this same principle of improved processes and greater production be invoked to reduce the cost of other electrical commodities and influence the expansion of the market —which means the increased consumption of electrical energy and the greater use of electrical appliances and accessories, to the benfit of our entire industry and all the people? It will be but natural for other manufacturers to say, "But lamps are different." Yet automobiles are unlike lamps. After all, it is not a matter of the nature of the product, but rather the potential capacity of the public to desire and assimilate. Few men could see the greatness of the demand for motor cars when Ford began to make his dream come true. And when the vastness of the market that lies ahead of the electrical industry is considered, no one can doubt that other great industrial pioneers will in other directions find the way in a manner no less spectacular in this field of unparalleled opportunity. Lamps have set a challenge to electrical men.—*Electrical World*, Feb. 16, 1924, p. 318.

4. Lighting of Streets—P. S. Millar, I. E. S.—U. of P. Lecture Course, 1916.

5. Rolph Toensfeldt, Department of Public Utilities, St. Louis *Electrical World*, Nov. 24, 1923, page 1065.

The Transmission Unit
and Telephone Transmission Reference Systems

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***Review of the Subject.**—Consideration is given to the method of determining and expressing the transmission efficiencies of telephone circuits and apparatus, and of the desirable qualifications for a unit in which to express these efficiencies. The "transmission unit" described in this paper has been selected as being much more suitable for this purpose under present conditions than the "mile of standard cable" which has been generally used in the past.*

* * * * *

THE "mile of standard cable" has been used in telephone engineering in this country for over twenty years, and during that time has been adopted in other countries, as the unit for expressing the transmission efficiency of telephone circuits and apparatus. In the present state of the telephone art, this unit has been found, however, to be not entirely suitable and it has recently been replaced in the Bell System by another unit which for the present, at least, has been called simply the "transmission unit." Before considering the reasons for such a fundamental change and the relative merits of the two units, it may be well to review briefly the general method of determining the efficiency of such circuits and the apparatus associated with them.

The function of a telephone circuit is to reproduce at one terminal the speech sounds which are impressed upon it at the other terminal. The input and output of the circuit are in the form of sound and its efficiency as a transmission system may be expressed as the ratio of the sound power output to the sound power input. For commercial circuits, this ratio may be of the order of 0.01 to 0.001.

In the operation of the system, the sound power input is converted by the transmitter into electrical power, which is transmitted over the line to the receiver and there reconverted into sound power. The effect of inserting a section of line or piece of apparatus or of making any change in the circuit can be determined in terms of the variation which it produces in the ratio of the sound power output to the sound power input, or, if this latter is kept constant, in terms of the ratio of sound power output after the change to that obtained before the change was made. It should be noted particularly that the change in the output power of the system is the real measure of the effect of any part of the circuit on the efficiency of the system and that the ratio of the power leaving any part to that entering it is not necessarily the measure of this effect. For example, a pure reactance placed in series between the transmitter and the line, may change the power delivered to the line by the transmitter and hence the output of the receiver, the magnitude and direction of the change being determined by the impedance relations at the point of insertion. The ratio of the power leaving the reactance to that entering it is, of course, unity, as no power is dissipated in a pure reactance. In other words, the transmission efficiency of any part of a circuit cannot be considered solely from the standpoint of the ratio of output to input power for that part, or the power dissipated in that part, but must be defined in terms of its effect on the ratio of output to input power for the whole system.

By determining the effect of separately inserting the many pieces of apparatus that may form parts of typical telephone circuits, an index can be established for each of these parts of its effect on the efficiency of the circuit for the conditions of which the circuit tested is typical. Similarly, the power dissipated in unit lengths of the various types of line can be determined by noting the change in power output of the receiver caused by increasing any line by a unit length. Such indices of the transmission efficiencies of the various parts of a circuit obviously have many applications in designing and engineering telephone circuits. These indices could be taken as the ratios expressing the change in the output power of the system. This, however, has certain disadvantages. For example, the combined effect of a number of parts would then be expressed as a product of a number of ratios. Likewise, for the case of a number of parts n of the same type in series, such as a line n miles in length, the effect would be expressed as the ratio for one part or one mile of the line, raised to the nth power. In many cases, these ratios and the powers to which they would need to be raised would be such as to make their handling cumbersome. If, however, these indices are expressed in terms of a logarithmic function of a ratio selected as a unit, the sum of any number of such indices for the parts of a circuit is the corresponding index for the power ratio giving the effect of the combination of these parts.

The "mile of standard cable" is such a logarithmic function of a power ratio. The new unit also meets this important requirement.

Definition of the Transmission Unit

The "transmission unit" (abbreviated *T U*) has been chosen so that two amounts of power differ by

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one transmission unit when they are in the ratio of $10^{\cdot 1}$ and any two amounts of power differ by N units when they are in the ratio of $10^{N(\cdot 1)}$. The number of transmission units corresponding to the ratio of any two powers P_1 and P_2, is then the common logarithm (logarithm to the base 10) of the ratic P_1/P_2, divided by 0.1. This may be written $N = 10 \log_{10} P_1/P_2$. Since N is a logarithmic function of the power ratio, any two numbers of units, N_1 and N_2, corresponding respectively to two ratios, P_a/P_b and P_c/P_d, may be added and the result $N_1 + N_2$, will correspond to the product of the ratios, $P_a/P_b \times P_c/P_d$.

The reasons for the selection of this unit and the method of applying it, can probably be best brought out by a consideration of the practise which has been followed in determining and expressing the efficiencies of telephone circuit and apparatus in terms of "miles of standard cable."

Standard Reference Circuit

Fig. 1 shows what has been designated the "standard reference circuit." It consists of two common battery telephone sets of the type standard in the Bell System at the time this circuit was adopted, connected through repeating coils or transformers to a variable length

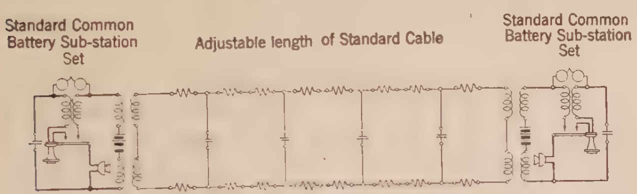

Fig. 1

of "standard cable." This cable is an artificial line having a resistance of 88 ohms and a capacity of 0.054 microfarad per loop mile which is representative of the type of telephone cable then generally used in this country.

For a given loudness of speech sounds entering the transmitter at one end of the circuit, the loudness of the reproduced sounds given out by the receiver at the other end can be varied by changing the amount of standard cable in the circuit. Also, the amount of cable in the circuit can be used to express the ratio of the power of the reproduced sounds to that of the impressed sounds. Due to the dissipation of electrical power in the cable, this ratio and consequently the loudness of the reproduced sounds become less as the amount of cable is increased and greater as the length of cable is decreased.

This circuit then became the measuring or reference system for engineering the telephone plant and the "mile of standard cable" became the unit in which the measurements were expressed. This circuit was used to set the service standards in designing and laying out the telephone plant. Thus, the reproduction obtained over this circuit with a length of cable of about twenty miles was found suitable and practicable for local exchange, that is, intra-city service, and that corresponding to about thirty miles for toll or intercity service.

Any telephone circuit was rated by its comparison with the standard circuit. This comparison was on the basis of a speaker talking alternately over the circuit to be measured and the standard circuit and a listener switching similarly at the receiving ends, the amount of cable in the standard circuit being adjusted until the listener judged the volume of the sounds reproduced by the two systems to be equal. The number of miles of cable in the standard circuit was then used as the "transmission equivalent" of the circuit under test. The effect of any change in the circuit under test on the efficiency of that circuit could then be measured by determining the variation in the amount of standard cable required to make the sounds reproduced by the two systems again equal and the number of miles of standard cable required to compensate for this change was used as the index of this effect. In this way the relative efficiencies of two transmitters or receivers could be determined. Likewise, the power dissipation per unit length or the attenuation, of the trunk in the circuit under test could be equated to miles of standard cable. Since in each case, the standard cable is used to adjust the volume of the reproduced sound, "the mile of standard cable" corresponds to the ratio of two amounts of sound power, or as this change in sound power is produced by changing the power delivered to the telephone receiver, to a ratio of two amounts of electrical power.

If the addition of a mile of standard cable to a long trunk of the standard circuit causes the power reaching the end of the trunk to decrease by a ratio r, then the insertion of two miles will decrease the received power by a ratio of r^2 of that obtained before the two miles were inserted. A number of miles of cable, n, inserted will reduce the received power to a ratio r^n. Thus the power ratio corresponding to any given number of miles of cable is an exponential function of the ratio corresponding to one mile, the exponent being the length in miles. The length in miles is, therefore, a logarithmic function of the power ratio.

In an infinite length of uniform line having resistance, inductance, capacity and conductance of R, L, C and G per unit length, the attenuation a per unit length, of a current of frequency f flowing along the line can be shown to be equal to the real part of the expression

$$a + j\,b = \sqrt{(R + j\,2\,\pi\,f\,L)\ (G + j\,2\,\pi\,f\,C)}$$

For the standard cable line, since L and G are zero

$$a = \sqrt{\pi\,f\,R\,C}$$

and since $R = 88$ ohms and $C = 0.054$ microfarad per mile the current attenuation per mile of standard cable is

$$a = 0.00386\,\sqrt{f}$$

If I_1' and I_2' are the currents, respectively at the beginning and end of a mile of line, then

$$I_1'/I_2' = e^a \text{ or } a = \log_e I_1'/I_2'$$

Similarly if I_1 and I_2 are the currents, at points 1 and 2, respectively, at the beginning and end of a section of L miles

$$I_1/I_2 = e^{La} \text{ and } L\,a = \log_e I_1/I_2$$

For this case, the effect of inserting the section of L miles into the line on the current at point 2, or at any point beyond 2, is that the currents at the point before and after the insertion are in the same ratio as I_1/I_2. Furthermore, since the impedance of the line looking toward the receiving end is the same at points 1 and 2 (and at any other points), then the ratio of the powers at the two points is equal to the square of the current ratio.

Thus the power attenuation is represented by

$$P_1/P_2 = (I_1/I_2)^2 = e^{2a}$$

Similarly for a line, terminated in a fixed impedance which may be different from the characteristic impedance of the line, the ratio of the powers received before and after a change in the length of the line is equal to the square of the ratio of the corresponding currents. On the basis of this relation, and because it is in general more convenient to measure or compute currents than powers, the current ratio has often been used in determining the equivalent of any piece of apparatus or line in terms of standard cable. It should be noted, however, that such a current ratio can be properly used as an index of the transmission efficiency of a part of a circuit only when it is equal to the square root of the ratio of the corresponding powers. Also, of course, the voltage ratio can be similarly used when it meets the same requirement.

Limitations in Use of Standard Cable Unit

As has been shown above, the attenuation, either of current or power, corresponding to the mile of standard cable is directly proportional to the square root of the frequency of the current under consideration. This means that the standard cable mile corresponds not only to a certain volume change in the reproduced speech sounds, but also to a distortion change. For comparisons between the standard cable circuit and commercial circuits with talking tests and as long as most of the commercial circuits had distortion comparable to that of standard cable, this two-fold effect of standard cable was desirable. At present, however, many types of circuits are being used which have much less distortion than standard cable. Also, the use of voice testing has been largely given up in the plant and it is now the general practise to determine the efficiency of circuits and apparatus on the basis of measurements and computations for single-frequency currents, a correlation having been established between these latter results and those of voice tests. These factors have made it desirable to have a unit for expressing transmission efficiencies which is distortionless, that is, is not a function of frequency.

Qualifications of a New Unit

The consideration of a new unit for measuring transmission efficiency brought out the following desirable qualifications:

1. *Logarithmic in Character*. Some of the reasons for this have already been discussed. In addition, the application of such a unit in measurements of sound make a logarithmic unit desirable, since the sensation of loudness in the ear is a logarithmic function of the energy of the sound.

2. *Distortionless.* The advantages of a unit which is independent of frequency have been referred to above. In expressing the efficiency of the transmission of the high frequencies involved in carrier and radio circuits, such a unit is particularly desirable.

3. *Based on Power Ratio.* This is desirable because the power ratio is the real measure of transmission efficiency. As pointed out above, the current ratio can be used only when it is equal to the square root of the power ratio. Having the unit based on a power ratio does not, of course, require that measurements or computations be made on a power basis.

In considering the conversions between sound and electrical energy, it is obviously advantageous to have a unit based directly on a power ratio.

4. *Based on Some Simple Relation.* This is desirable in connection with the matter of getting a unit which may be widely used and may find applications in several fields.

5. *Approximately Equal in Effect on Volume to a "Mile of Standard Cable."* One reason for this is the practical one of avoiding material changes in the conceptions which have been built up regarding the magnitude of such things as transmission service standards. Also, the sound power changes which can be detected by the ear are of the order of that corresponding to a mile of standard cable. In measuring telephone lines and apparatus with single-frequency currents, it has been found that an accuracy of about one-tenth of a mile can be obtained readily and is sufficient practically.

6. *Convenient for Computations.* This refers to the matter of changing from computed or measured current or power ratios to transmission units or vice versa.

Properties of the Transmission Unit

A consideration of the above qualifications and of the various units suggested, led to the adoption of the power ratio of $10^{.1}$ as the most suitable ratio on which to base the unit of transmission efficiency. The transmission unit is logarithmic, distortionless, is based on a power ratio and its relation to that ratio is a simple onr. Its effect on the transmission of telephonic powee corresponding to speech sounds is about 6 per cent less than that of one mile of standard cable. Regarding its use in computations, it has the advantage that the number of units corresponding to any power ratio, or current ratio, can be determined from a table of common logarithms.

For a power ratio of 2, the logarithm is 0.301 and the corresponding number of units is, therefore, this

logarithm multiplied by 10, which is 3.01 *T U*. For a power ratio of 0.5, the logarithm is 9.699−10 = −0.301 and the number of units is −3.01 *T U*. A power ratio of 2 represents a gain of 3.01 units, and a power ratio of 0.5 corresponds to a loss of 3.01 units. If the above ratios were for current, the logarithms would be multiplied by 20. Thus a current ratio of 2 corresponds to a gain of 6.02 units and a current ratio of 0.5 corresponds to a loss of 6.02 units.

It will be noted that the *T U* is based on the same ratio $10^{\cdot 1}$ as the series of preferred numbers which has been used in some European countries and has been proposed here as the basis for size standardization in manufactured articles.[1] In common with this series, the *T U* has the advantage that many of the whole numbers of units correspond approximately to easily remembered ratios as shown in the following table.

APPROXIMATE POWER RATIO

Transmission Units	For Losses Fractional	For Losses Decimal	For Gains Decimal
1	4/5	0.8	1.25
2	2/3	0.63	1.6
3	1/2	0.5	2.
4	2/5	0.4	2.5
5	1/3	0.32	3.2
6	1/4	0.25	4.
7	1/5	0.2	5.
8	1/6	0.16	6.
9	1/8	0.125	8.
10	1/10	0.1	10.
20	1/100	0.01	100
30	1/1000	0.001	1000.

It will be seen that the ratio for a gain of a given number of *T U*, is the reciprocal of the ratio for a loss of the same number of units. Also for an increase of 3 in the number of units, the loss ratio is approximately halved and the gain ratio doubled. If the approximate loss ratios corresponding to 1, 2 and 3 units are remembered, the others can be easily obtained.

From this consideration of the properties of the transmission unit, it is evident that there is much to commend its use in telephone transmission work. Furthermore, since its advantages are not peculiar to this work, such a unit may find applications in other fields. It is now being used in some of the work on sound.

New Telephone Transmission Reference System

With the standardization of the distortionless unit of transmission it is desirable also to adopt for a transmission reference system a telephone circuit which will be distortionless from sound input to the transmitter to sound output from the receiver. This system will consist of three elements, a transmitter, a line and a receiver. Each will be designed to be practically distortionless and the operation of each will be capable of being defined in definite physical units so that it can be reproduced from these physical values. Thus the transmitter element will be specified in terms of the ratio, over the frequency range, of the electrical power output to the sound power input, this ratio being expressed in transmission units. The receiver element will be specified likewise in terms of the ratio of sound power output to electrical power input. The output impedance of the transmitter and the input impedance of the receiver elements will be 600 ohms resistance. The line will be distortionless with adjustments calibrated in transmission units and will have a characteristic impedance of 600 ohms resistance.

Such a reference system is now being constructed. The transmitter element consists of a condenser type transmitter and multi-stage vacuum tube amplifier. The receiver element consists of an amplifier and specially damped receiver. Each element is adjusted to give only negligible distortion over the frequency range.

It is proposed when this system is completed and adjusted that it will be adopted as the Transmission Reference System for telephone transmission work. Other secondary reference systems, employing commercial-type apparatus will be calibrated in terms of the primary system and used for field or laboratory tests when such commercial type systems are needed.

1. Size Standardization by Preferred Numbers, C. F. Hirshfeld and C. H. Berry, Mechanical Engineering, December, 1922.

HIGH-VOLTAGE UNDERGROUND CABLE

A new high voltage underground cable, carrying 50 per cent higher voltage than has hitherto been possible in this country, and twice as much power as any previous underground cable, was recently placed in operation in Cleveland. The cable, carrying 66,000 volts, now forms part of the transmission lines of the Cleveland Illuminating Company, a subsidiary of the North American Company.

Necessity for the construction of this high tension superpower cable arose from the need to supply power to interior territory in Ohio, Pennsylvania and West Virginia, where water for power plants is not available. Involved in the group connected by this project are eleven power companies.

As its share in the project, the Cleveland Company had to tie into the overhead high-tension lines of the Northern Ohio Traction Company, 20 miles from the Cleveland generating station. More than eight miles of this distance are in the thickly populated residential and business sections of the city. Overhead lines being out of the question, the engineers finally decided to adopt a 66,000 volt cable and a subway was accordingly built across the city with manholes placed at about 400-foot intervals.

About 200,000 feet of this cable was used. An interesting feature of the installation was the testing of the finished line of cable at 152,000 volts, direct current, one of the recently developed kenotron cable-testing equipments being used.

Present Practise in the Automatic Operation of Hydroelectric Generating Stations

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Review of the Subject.—*Present practise in the design of automatic hydroelectric generating stations is reviewed. Various methods of starting and controlling are listed together with their limitations. Certain points in dispute, such as the $W R^2$ required for speed regulation and brakes for bearing protection are presented in the hope that discussion will aid in clarifying the situation to such a degree as to permit of standardization of practise. A brief description of the sequence of operations in a modern automatic switching equipment, is given.*

* * * * *

THE advantages to be gained by the automatic operation of hydroelectric generating units are now so well known that their recapitulation is unnecessary at this time. It is the purpose of this paper to present a brief but comprehensive outline of present day practise as applied to such units.

Hydraulic Development

The elimination of the cost of manual operation makes possible a much different treatment of many hydraulic developments. As the cost of the hydraulic development is usually a large item in the total cost of the water power station, this item should be considered carefully in the light of possible savings incident to the employment of automatic control. By splitting up the total available head into two or more smaller heads, a considerable saving in the purchase of flowage rights is possible. Against this must be balanced the higher cost of wheel and generator per kilowatt. As the cost of the actual dam rises rapidly with increasing height there is some saving in this item. A careful balance of the cost items entering into construction of any given development should always be made to see that no further economies are possible before any given distribution of the available head is finally adopted. Careful consideration will many times enable the production of kilowatt hours at a lower figure than possible with the old method of maximum head for a few plants. The modern method involves the use of many small units with lower heads for each and with automatic control.

Types of Wheels

Most of the automatic water power stations that have been supplied have been of the low head variety, the working heads varying from a minimum of 9 ft. to 75 ft. They are the reaction or Francis type and the propeller type, of which the Nagler is a good example. The latter is noted especially for the high specific speeds possible on very low heads with a consequent economy in generator cost. However, efficiencies of the two wheels at the average loads expected should be carefully compared, as a reduction of a few kilowatt hours in the station output will soon nullify any saving in the first cost. As the efficiency curves for the two types are not of similar shapes for varying combinations of head and size, no general rule can be adopted. A careful analysis of each project should be made before a definite type of wheel is selected.

The foregoing remarks apply to vertical wheels which are almost universally used for low heads. There are a few engineers who yet cling to the horizontal reaction wheel. Correct application of this type of wheel to low head installations are rare. Efficiencies equivalent to those obtainable with the vertical type are difficult to secure. Construction of the building and penstock will be more expensive while the generator will cost somewhat less.

For small units and high heads the impulse wheel is used exclusively. It is customary to build the generator with extra large bearings and mount the runner outboard on the generator shaft.

Operation with Respect to Remaining System

There are several possible methods of operation and control, the selection of any specific type depending upon the conditions of the system. The more usual methods are listed below.

(a) Fixed gate opening.

(b) Regulation of load with respect to head of water available.

(c) Regulation of speed by centrifugal governor.

Form (a) is used where a relatively small unit is closely tied to a large system which can absorb all the power generated at all times and which has other units under control of speed governors. Two forms of automatic water control are available. The head gates or the wicket gates may be opened wide by an electric motor supplied with energy from a control transformer or from the station battery if there be such. An oil pressure device may be used with a construction similar to the speed governor but without a centrifugal element. A small solenoid valve admits oil to the servo-motor and causes the wicket gates to open, a float switch is used to start the wheel when excess water is available and to stop it when the forebay is lowered to the desired limit. No intermediate steps are possible.

Form (b) is used where surplus water is used from a

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source in which a specified head must be maintained at all times. If oil-operated gates are used, a float switch is caused to actuate a pilot valve, which in turn actuates the servo-motor in such a manner as to draw a predetermined amount of water for a given head. If electrically operated gates are used, the float switch is caused to actuate a pilot valve, which in turn actuates the servo-motor in such a manner as to draw a predetermined amount of water for a given head. If electrically operated gates are used, the float switch actuates a contact device, which in turn energizes the motor on the gates to increase or decrease their opening. An anti-hunting device is mechanically connected to the gate mechanism and the contact device.

Method (c) is that most widely used and is to be recommended for most applications. Units equipped with speed governors may be safely operated on any size or type of system. Water-level control may be added to the speed control if desired. Most modern governors consist of an oil pressure tank, a centrifugal device, a valve mechanism and a servo-motor or oil cylinder for the actual mechanical operation of the wicket gates. Past practise has been to drive the centrifugal element from the main generator shaft by a belt. This drive is rapidly being replaced by one employing a small synchronous motor energized from potential transformers connected to the generator. If belt drive is used in an automatic station, an automatic trip should be connected to the idler pulley so that breakage of the belt will take the unit out of service. In an automatic station where a self synchronizing generator is used, the synchronous driving motor is not energized until after the oil switch is closed. There may be some overspeeding as a result of such operation, but as the modern wheel and generator are built to stand the maximum speed obtainable with gates open wide and no load on the generator, no trouble need be anticipated from such excess speed.

Oil pressure for the operation of the governor is obtained from a pump and stored in a closed reservoir against air pressure. The pump may be belt-driven from the generator shaft or motor-driven by a polyphase a-c. motor supplied from transformers connected to the a-c. bus. The latter method is much to be preferred. If a station battery be available an emergency pump may be operated with a d-c. motor. It is customary to provide an oil pressure relay set to cut off the station while there is yet sufficient oil pressure in the reservoir to close the gates.

The governor is equipped with one or more control solenoids which operate small auxiliary oil valves, which in turn open the main valves to the servo-motor. In one form of governor there is but one solenoid which opens the governor wide, but under the retarding influence of a dash pot. With the control methods in general use there is some overspeeding until the generator is connected to the line, as the synchronous motor driving the centrifugal element is not energized until that time. A second form uses one solenoid to open the gates just enough to accelerate the wheel to synchronous speed, the second solenoid being energized after the generator is connected to the line. This second solenoid causes the governor to open wide but under control of the speed governor, which is now operative because the synchronous driving motor is energized. Both forms of control keep the solenoids energized throughout the period of operation. To stop the wheel the solenoid circuit is opened. The gates immediately close and the wheel stops.

As the gate movement is necessarily slow and the response of the wheel to the governor is therefore slow, a certain amount of flywheel effect is necessary to stabilize the generator during rapid changes in load. The importance of this effect is greatly over-estimated as a large system is a very effective flywheel in itself. The amount of inertia required is expressed by the well-known formula WR^2. The amount required is specified by the waterwheel manufacturer, but supplied by the generator builder either in the form of additional weight in the rotor or by the use of a separate flywheel. Since the wheel builder is not penalized by his inertia requirements he usually specifies rather more than less than enough. Much money is wasted in following these excessive requirements. Engineers with small hydro projects to execute would do well to investigate the available flywheel effect of their systems before purchasing a lot of useless cast iron attached to their generators.

Brakes

There is some dispute regarding the necessity for automatically-operated brakes to stop the wheel when rubbish or erosion causes enough leakage to operate the wheel at low speeds. If the thrust bearing operates at low speeds it will not carry enough oil between the bearing surfaces to maintain separation. If the wheel continues to rotate, the bearing will be destroyed. Some engineers insist that brakes be applied to definitely stop rotation when the gates are closed. Other engineers maintain that when only enough water is passed to rotate the wheel slowly with oil between the surfaces, there will be an enormous increase in friction when the oil film is squeezed out. Such increased friction will result in stoppage of the wheel before damage is done. Since a difference of opinion exists, it is suggested that this point be stressed in discussion so that the practise regarding the application of brakes may be standardized.

Where brakes are used, they may be operated by oil pressure from the governor reservoir or by a separate source of air pressure. While the amount of oil required is not large, this item should not be overlooked when purchasing the governor. Oil pressure may be applied through the medium of magnet valves or through valves mechanically actuated by the movement of the water-wheel gates. Air pressure may be applied

through magnet valves of the kind developed for electro-pneumatic railway control.

Brakes of the oil pressure variety seem slightly less objectionable than the air-operated type because of the necessity of an automatically operated compressor for the latter. As any automatic station is improved by simplification, it would be highly desirable to eliminate automatically controlled brakes, if the designers of thrust bearings could agree to this as standard practise. Hand-operated brakes should be furnished for holding the wheel when the unit is being cleaned or repaired, if no automatic brakes are used.

Bearing Lubrication and Protection

The usual circulating oil system with self-contained pump, driven from the generator shaft, is customarily used in automatic stations for lubrication of the thrust and guide bearings. No automatic devices have been worked out for the lubrication of the wicket bearings, although some inexpensive simple system would seem warranted. Even the present grease-cup method is not entirely adequate because there is usually no method of insuring equal distribution of grease between the upper and lower wicket bearings. This is a problem the waterwheel manufacturers should take steps to solve.

Thermostat protection should always be provided for all main bearings. The guide bearings of vertical machines and the main bearings of horizontal machines should have the active element in actual contact with the babbit. In the horizontal type this contact should always be established at the center of the bottom of the bearing, as this is the point of greatest pressure and consequent heating. The thrust-bearings of vertical machines are customarily operated under oil. The temperature of the oil is therefore a good clue to that of the bearing. The active element of the thermostat is immersed in the oil near the thrust surfaces. Most of the thermal devices used for bearing protection are of the vapor-expansion type, which insures ample energy for operation of contacts. These devices are made suitable for the bearing to be protected and are not provided with adjustments for changing the temperature at which operation of the contacts is effected.

Generator Characteristics and Equipment

The generators used in modern unattended stations should be of the self-synchronizing type. To prevent disturbance to the system at time of connection to the line, these generators should have as high a reactance as is feasible, to limit the rush of current when the oil breaker is closed. Heavy damper windings are necessary to quickly pull the generator in step with the line. These generators are usually accelerated to approximate synchronous speed and then connected to the line before excitation is applied. Immediately after the closing of the breaker, the field switch is closed. The normal time element introduced by the high inductance of the field winding is sufficient to prevent excessive mechanical stresses in the windings.

Generators for unattended stations with automatic control should always be equipped with direct connected exciters. There are a few exceptions to this rule, such as excitation drawn from d-c. lighting net work or from an excitation bus in an adjoining station. Belted exciters should be avoided even though the reduction in price makes this type apparently desirable. Troubles may be expected with the belt and with the idler pulley.

Two forms of speed relays are used for indicating approximation to synchronous speed. A centrifugal switch may be attached to the end of the generator shaft or a specially designed magneto generator may be geared to the shaft, its voltage, as indicated by a relay, constituting the desired indication.

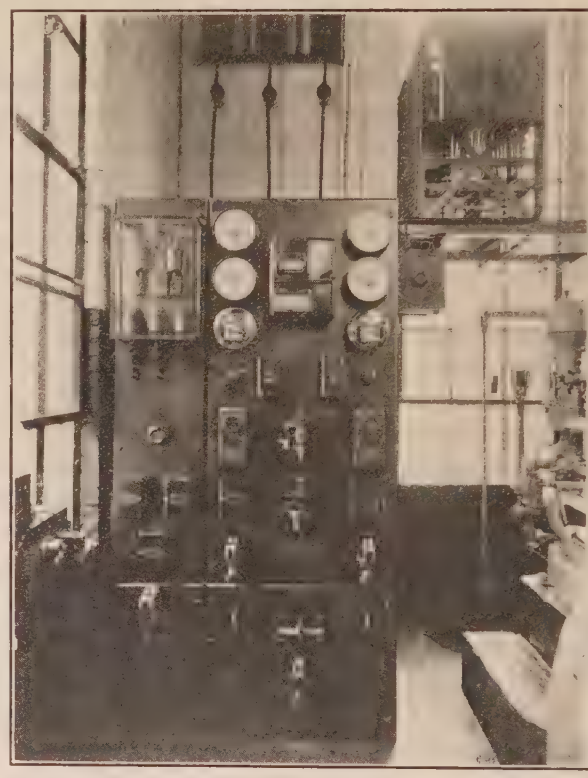

Fig. 1—Small Automatic Hydroelectric Generating Station with Vertical Self-Synchronizing Generator. This is a Typical Installation

A second element in the centrifugal switch or a second voltage relay on the magneto is used to indicate excessive speed.

Functions of Control Equipment

The initial starting indication for the automatic control may be obtained in any one of several ways. The following list covers the majority of the methods which have been used or discussed.

(A) Water level.
(B) System frequency.
(C) Remote control by pilot wire.
(D) Supervisory control over the telephone circuit.

(E) Manual operation of control switch in station.
(F) Control by manipulation of the a-c. line.
(G) Control by time switch.

Combinations of one or more of the above have been used in several installations. Where the station is controlled entirely by (A) the indication is obtained from a float switch which makes contact when the water in the forebay rises above a predetermined point. Some small systems are using the method (B) to call additional capacity into service when the drop in system frequency indicates an overload on the generating equipment in service. This method has a very limited application to systems fed principally from small water plants. If any steam turbine stations are used, the overload capacity of the turbine will maintain the normal frequency and defeat the purpose of the automatic station. If several automatic stations are used on the same system with this form of control, there is no suitable method of selection, therefore several stations may be called into service when only one is wanted. If differential timing is attempted, the time required to start the last stations is prohibitive since it must exceed all the time required for the first stations to start and connect to the line.

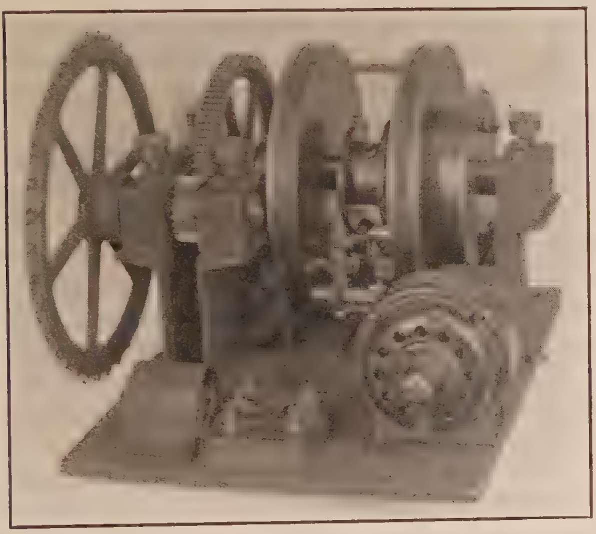

Fig. 2—Contact Device with Electrically Operated Anti-Hunting Mechanism for Automatic Control of Water Level in Forebay. This Device is Located About 2000 Ft. from the Station it Controls which Contains a 1000-Kv-a. Generator and Impulse Wheel Operation on 450-ft. Head

Method (C) is suitable where the distance to an adjoining station with manual operation is not excessive. Method (D) is being used to a large extent in the stations being installed at the present time. There are several types of equipment available at a wide range in price. By the use of some of these it is possible to control the starting and stopping of the unit, the load, the voltage, and the outgoing feeders. The same equipment enables the distant operator to ascertain the available head of water, the gate opening, the load in kilowatts, the condition of the feeders and any other indications that may be desired. All these functions may be obtained with the various forms of equipment over circuits of from two to four wires, which wires may be used for magneto or local battery telephones. None of these systems will work on the same circuit with common battery telephones.

Where natural conditions and the size of the plant warrant the expense, it is customary to have one resident maintenance man who starts and stops the station with a control-switch method (E) as instructed by the load dispatcher. This man is not expected to remain in the station but is subject to call by the dispatcher whenever required. A siren on the station roof is frequently used for this purpose.

Method (F) is occasionally employed where the automatic station is on an independent line which may be switched from another station. The station is started by closing the oil switch on the line in the manual station. An a-c. voltage relay then causes the unit to be started. Upon opening the oil switch the machine will be tripped by overspeed, due to the sudden reduction in load, or by a contact on the waterwheel gate which is closed in the no-load position, which position the governor will promptly cause the gates to assume, if the overspeed trip does not have a chance to operate.

Method (G) may be employed where hydroelectric units are used to supply energy to industrial plants having fixed working hours or to switch on additional capacity in advance of known periods of peak load.

In addition to the automatic means described above, there are two methods of partial automatic starting, one by means of a multi-wire control and actual synchronizing by hand, the other by actual hand starting with protective features so that the station may be permitted to operate without an attendant.

Current for the operation may be drawn from a transformer connected to the a-c. line or from a small storage battery maintained in a charged condition by automatic devices with current from the exciter. If the first method is used, the unit cannot be put into service unless the line voltage is above 80 per cent normal. If the second method is used, the unit may be put into service regardless of the line condition.

Sequence of Operations

The usual sequence of operations after the initial starting signal is given by any one of the automatic indications is mentioned below.

(1) The master relay is energized.

At this time the exciter-field rheostat is short-circuited to aid the exciter to build up to normal voltage as rapidly as possible. The generator-field contactor is in the de-energized position, its back contact shorting the field through a discharge resistance.

(2) The governor solenoid is energized.

The gates are thus caused to open and the unit accelerates. The exciter builds up rapidly.

(3) At an approximation of synchronous speed the speed-indicating device closes the control for the oil switch. The closing energy for this switch is obtained from the exciter. If the voltage has not built up to the minimum operating point for the breaker, there will be a slight delay in closing until the voltage does reach this point.

(4) The oil switch closes, connecting the unexcited generator to the a-c. line. The short circuit is also removed from the exciter field rheostat. The circuit of the field-switch operating coil is energized.

(5) The field switch closes, connecting full excitation to the generator field. The generator pulls into step with the line and as the gates continue to open, picks up its load.

The normal sequence of operations provides for the shutting down of the unit without disturbance by first de-energizing the governor solenoid to close the gates and then tripping the oil breaker with a contact on the gate mechanism at the position corresponding to no load. The field switch is then opened and the brakes, if any, are applied.

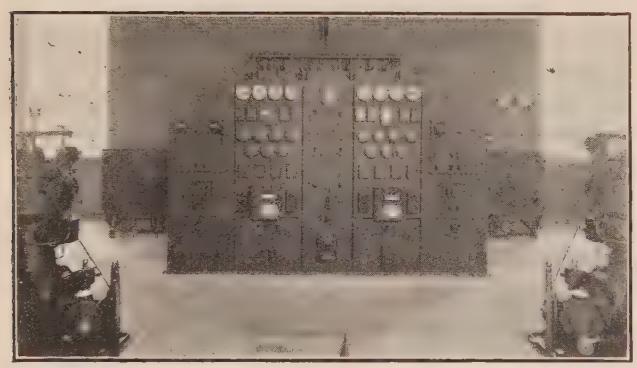

Fig. 3—Switchboard for the Automatic Operation of Two-2200-Kv-a. Waterwheel Generators. The Large Square Case in the Center of Either End Panel is the Speed Matching Device. Above is the Automatic Synchronizer and Below is the Control Element of the High Speed Rheostatic Regulator

Regulation of Voltage

There are several methods of operation with regard to voltage control. Those in general use are as follows:

(1) Fixed excitation. This is only applicable where the automatic unit is electrically close to a regulated generator and where it carries a considerable proportion of its full load at all times.

(2) Regulation by the standard vibrating regulator.

(3) Regulation by a contact-making voltmeter and an ordinary motor-operated field rheostat in the generator circuit.

(4) Regulation by the high-speed rheostatic regulator.

With any one of the three types of regulation it is necessary that some form of wattless compensation be employed, so that the automatic unit will not carry an undue share of the wattless load of the system.

Protective Features

As the automatic stations must operate under all conditions without human attention, it is necessary that the generator be protected against almost every imaginable operating contingency. It is manifestly impossible to anticipate all forms of trouble and it is manifestly impracticable for financial reasons to furnish protective devices for the extremely remote contingencies; therefore it is customary to disregard those troubles which require the coincidence of two or more improbable events to damage the machine.

All larger generators are equipped with balanced relay protection to open the breaker and field switch should there be an insulation failure. The cost of this protection is considerable and an arbitrary lower limit of 500 kv-a. has been set, below which it is not customary to furnish such protection.

Two thermal relays are connected in the secondary circuits of the current transformers to measure the heating effect of the output of the generator. Should the safe limit of heating be approached, these relays will shut down the unit until cooled down, after which restarting is permitted.

Field failure is caught by a relay in series with the generator field with a time element sufficient to bridge over any ordinary surge.

Short circuits external to the station are caught by two different means. The first employs the usual overload relays and shuts down the unit until the rise in a-c. line voltage, fed from other stations, indicates that the trouble has been remedied. The second method uses the line voltage as an indication of trouble and allows the machine to deliver as much current as it is able, until the reduction in voltage operates a line voltage relay or until a thermal relay operates. The machine is reconnected on rise in line voltage as in the first case.

It is advisable to provide protective devices against excessive rise in either exciter or generator voltage. Relays which form a crude vibrating regulator insert large amounts of resistance in the exciter field under either of such emergencies.

Any high-tension equipment should be located outside the building. The high-tension construction should be as simple as possible, without any high-tension circuit breaker if the unit be under 500 kv-a. The arrester should be of the non-fluid type which require no charging or attention. A separate set of disconnecting switches should be provided for the arresters.

Special Forms of Control

When a generator forms too great a percentage of the total generation to permit of self-synchronizing, or if the generator be difficult or expensive to equip with damper windings, an automatic speed matcher and synchronizer is available. The speed matcher consists of two small synchronous motors, one for the machine and one for the bus. These are connected to a me-

chanical differential, which in turn is connected to contacts which control the speed-adjusting motor on the waterwheel governor. Any difference in speed of the two motors results in a movement of the differential and consequent operation of the adjusting motor. The speed of the wheel is thus adjusted as though in an ordinary manual station. The automatic synchronizer awaits the first favorable point and closes the breaker. The governor is then opened wide to pick up the load.

It is also possible to ease the shock of self synchronizing by the use of current-limiting reactors which are connected between the machine and the bus until synchronous operation is attained. The reactors are then shorted by a second breaker. The same result may be obtained if step-up transformers are used for the output by synchronizing with a low voltage tap, after which the generator is transferred to full voltage just as a tap-started synchronous motor is controlled.

High head plants offer additional problems in control, as the velocity of the water is so great that it must be handled with great care. Load control is usually had by opening or closing the needle valve with a motor. The deflector which is used for speed control should be interconnected with the needle-valve control so that there will be no unnecessary waste of water off the deflector. Thus if the wheel is carrying 90 per cent load and system conditions cause the wheel to drop to 70 per cent load, the deflector will be wasting 20 per cent of the water. The automatic control should promptly close the needle valve sufficiently so that this 20 per cent of water may be saved. Hydraulic engineers will doubtless question the accuracy of these figures but the percentages are intended only for illustration.

In order that the small automatic generating stations may prove to be a financial success, it is obvious that construction costs must be minimized. Past manual practise in building design and equipment should be forgotten. It should be remembered that extreme simplicity of construction, small units located at frequent intervals and entire absence of emergency switching or reserve capacity in any one station, will deliver more kilowatt hours at less expense than a few large units with expensive hydraulic development, elaborate emergency equipment and fine buildings.

ELECTRICAL STRUCTURE OF MATTER

All men deal with matter in the gross and our bodies are of it constructed. Mysteries of matter, therefore, have a fascination for thoughtful laymen, as well as scientists and technologists. The atom has long been familiar as the ultimate unit of matter.

* * * * * *

Our whole conception of the atom was revolutionized by the study of radioactivity. The discovery of radium provided the experimenter with powerful sources of radiation specially suitable for examining the nature of the characteristic radiations emitted by the radioactive bodies in general. The wonderful succession of changes that occur in uranium, more than thirty in number, was soon disclosed.

It was early surmised that electricity was atomic in nature. This view was confirmed and extended by a study of the charges of electricity carried by electrons. Skillful experiments by physicists added to the knowledge of the subject. One of the main difficulties has been the uncertainty as to the relative part played by positive and negative electricity in the structure of the atom. The electron has a negative charge of one fundamental unit, while the charged hydrogen atom has a charge of one positive unit. There is the strongest evidence that the atoms of matter are built up of these two electrical units.

It may be of interest to try to visualize the conception of the atom we have so far reached by taking for illustration the heaviest atom, uranium. At the center of the atom is a minute nucleus surrounded by a swirling group of 92 electrons, all in motion in definite orbits, and occupying but by no means filling a volume very large compared with that of the nucleus. Some of the electrons describe nearly circular orbits round the nucleus; others, orbits of a more elliptical shape whose axes rotate rapidly round the nucleus. The motion of the electrons in the different groups is not necessarily confined to a definite region of the atom, but the electrons of one group may penetrate deeply into the region mainly occupied by another group, thus giving a type of inter-connection or coupling between the various groups. The maximum speed of any electron depends on the closeness of the approach to the nucleus, but the outermost electron will have a minimum speed of more than 600 miles per second, while the innermost K electrons have an average speed of more than 90,000 miles per second, or half the speed of light.

The nucleus atom has often been likened to a solar system where the sun corresponds to the nucleus and the planets to the electrons. The analogy, however, must not be pressed too far. Suppose, for example, we imagined that some large and swift celestial visitor traverses and escapes from our solar system without any catastrophe to itself or the planets. There will inevitably result permanent changes in the lengths of the month and year, and our system will never return to its original state. Contrast this with the effect of shooting an electron through the electronic structure of the atom. The motion of many of the electrons will be disturbed by its passage, and in special cases an electron may be removed from its orbit and hurled out of its atomic system. In a short time another electron will fall into the vacant place from one of the outer groups, and this vacant place in turn will be filled up, and so on until the atom is again reorganized. In all cases the final state of the electronic system is the same as in the beginning. Sir Ernest Rutherford in "*Research Narratives.*"

22,000-kv-a. Transformers for Niagara Falls Development

BY F. F. BRAND

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During the past year the Niagara Falls Power Company has put into service the first unit of an extension which will contain the three largest water wheels and generators at present in the world, each generator having a maximum rating of 65,000 kv-a. at 12,000 volts and 25 cycles.

The limited width of the right-of-way from generating station, actually only the space over an existing intake canal, necessitated stepping up to 66,000 volts to transmit 195,000 kv-a. from the complete extension.

Transformers were therefore installed on an extension of the forebay wall. These are single-phase oil-immersed water-cooled 22,000-kv-a. connected delta on the 12,000-volt side and in *Y* on the 39,500-volt side to give 68,500 *Y*.

The principal interest in these transformers is, of course, in their large size and in the construction used to obtain high efficiency. The only single-phase transformers which exceed these in output are some 60-cycle 23,600 kv-a. units of the Duquesne Light & Power Co., Pittsburg, but since the Niagara transformers are 25 cycles, the parts, if used for a 60-cycle design, would give far greater output than any existing transformers.

In these transformers it was desired to obtain the maximum efficiency at ⅞ full load, at which point the transformers would probably be loaded most of the time, as it corresponded to maximum water-wheel efficiency.

With the maximum permissible magnetic density in present day silicon steel, to keep the magnetizing current and core temperature within reasonable limits, the loss at 25 cycles in the steel is about 1 watt per pound, while the loss in the copper in the winding is from 8 to 16 watts per pound. To obtain highest efficiency at ⅞ load it was necessary to use fewer turns and a correspondingly greater core section than would ordinarily be used and this accounts for the type of core construction used, *i. e.*, with the winding on the central leg of the core.

To meet certain specified conditions of line regulation, it was necessary that the product of per cent magnetizing current and impedance should not exceed a certain constant value. This naturally resulted in a design being used giving the minimum effective area of the leakage flux path between high-tension and low-tension windings. The spacing between high tension and low tension windings is ordinarily that required for insulating these windings from one another, and this distance and a fractional part of the coils themselves constitute the effective width of the leakage flux path. The magneto mechanical forces between high-tension and low-tension windings in 25-cycle transformers are usually higher than for higher frequencies. A design having a very large core area and flux and minimum area of leakage flux path would therefore be subject to higher magneto mechanical forces, both at normal load and under short-circuit conditions.

This can readily be understood when we consider that the mechanical force varies as the square of the leakage flux density between high-tension and low-tension windings and that with concentric windings the area of the leakage flux path varies as the diameter, whereas the area of the core varies as the square of its diameter, and that under short circuit conditions with sustained voltage the whole of the flux ordinarily in the core must pass between the high-tension and low-tension windings. The magneto mechanical forces would, therefore, vary approximately as the square of the core diameter.

The type of construction used is that known as the concentric circular coil type, in which the low-voltage winding consists of a single circular helix, adjacent to the central core member, and the high-voltage winding a series of circular disc coils arranged in cylindrical assembly outside of and concentric with the low-voltage winding.

In this type of winding the principal magneto mechanical forces between high-tension and low-tension windings are radial. The circular coil is self-sustaining against such forces, provided their value is not sufficient to exceed the elastic limit of the copper or insulation in tension or compression. If these values are not exceeded, it is only the unbalanced forces, due to the coils being assembled with the magnetic centers not co-incident, that must be considered seriously, as the coils are not self-sustaining against such axial forces.

The usual method is to provide bracing against the axial force, calculated by assuming certain definite but very conservative axial displacement of the coils to allow for variations in assembly and to add to this any displacement caused by taps which are taken off center.

To reduce the axial short-circuit forces as much as possible, the tap coils were so connected that an equal number of turns were tapped out each side of the center of the coil stack as shown in Fig. 1. Thus, the forces could only be those due to variations in assembly, which are quite small. The design calculations were based on an arbitrary displacement much greater than would be expected in practise.

Presented at the Spring Convention of the A. I. E. E., Birmingham, Ala., April 7-11, 1924.

Due to the self sustaining feature of circular coils against radial forces and the easy provision of bracing against axial forces, the circular-coil type of transformer can be readily designed to resist short circuit forces in all directions. In this it differs from types of transformers with non-circular coils, in which the coils tend to assume a circular shape during short circuits and which are difficult to brace against such coil distortion. In fact, this problem is so difficult that the forces, due

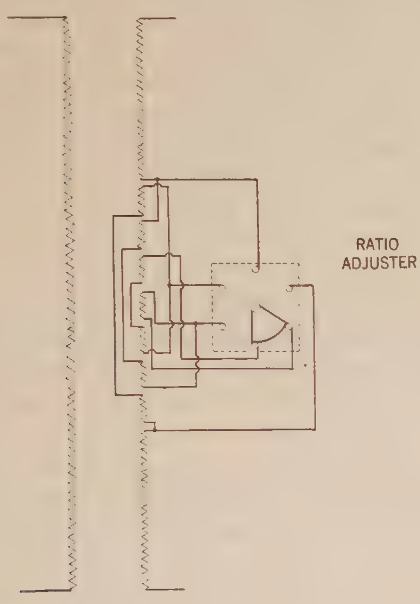

Fig. 1

to dissymmetry of the coils or variations in assembly, are usually neglected and no adequate bracing used to prevent distortion of this kind.

Each bank of three transformers is connected directly to one generator, so that for short circuits on the high-voltage side the generator reactance would be effective in limiting the short-circuit current to a lower value than that which would flow, if the transformer reactance alone were the limiting feature. In case of a short circuit on the low-voltage side, which is rather a remote possibility, power would be fed back from the rest of the system and the short-circuit current would be higher. To sustain the voltage under a short circuit would require a power flow of 66,000 kv-a. through one transformer bank having 10 per cent reactance.

The present system is not large enough to cause this power flow, as the voltage would fall and the short-circuit power flow be less. Conditions are, however, changing rapidly, power systems growing and it is not good engineering to consider existing conditions as giving the limiting conditions to be met in the expected life of the transformer. No allowance therefore was made for any external reactance in the short-circuit calculation, the transformer being designed to withstand short circuit with fully sustained voltage.

In building transformers to stand short circuits, it is essential to consider the tremendous vibration of the coils set up by the magneto mechanical forces, especially at 25 cycles. Tests made at Schenectady on the special short-circuit generator have shown the absolute necessity of designing the coil bracing, particularly the coil spacers, so that they will not fall out of place and thus out of alignment with each other.

A description of the spacing arrangements may therefore be of interest. The essentials of coil bracing are:

1. To support every turn at such intervals that the short-circuit forces will not exceed the tension of compression limits on the conductor and insulation.

2. To support the turns in such a manner that a minimum amount of conductor is covered in the direction of heat flow, otherwise, the conductor covered by the spacers may heat up so much that the insulation may be damaged or the tensile strength decreased long before the conductors exposed to the cooling medium reach such limits.

3. To lock every spacer in place securely against movement by vibration.

4. To arrange the spacers so that they are easily inspected during and after the coils are assembled.

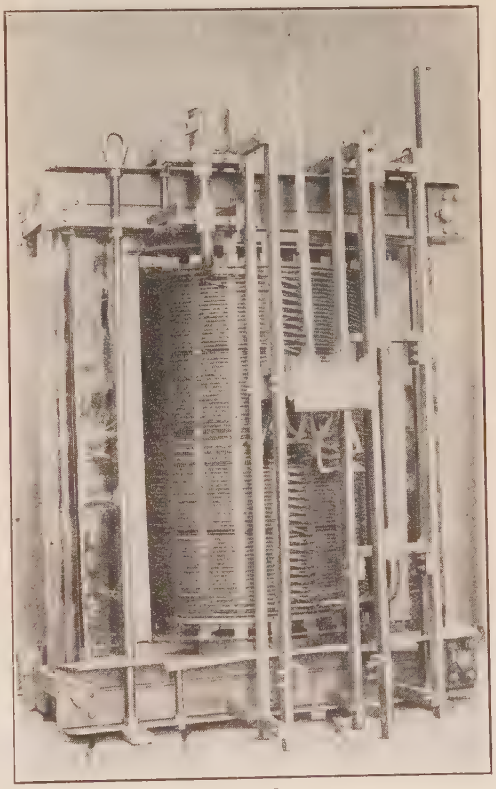

Fig 2

The coil spacers in these circular coil transformers and in others, built by the same manufacturer, are arranged radially across the face of the disc coils and the turns of the helical coils. This provides support for all conductors at approximately equal intervals.

Since the spacers are relatively narrow, two in. (5 cm.) wide as a maximum, the maximum distance of heat flow from that part of the conductor, covered

by a spacer to the cooling oil, is one inch. This precludes a great difference of temperature between the part of the conductors covered by the spacers and that exposed to the oil.

The spacers between turns on the low voltage helical coil are radial. They are dovetailed onto spacers arranged axially inside the coil, which are mounted on the insulating cylinder between coil and core on which the coil is wound. The axial spacers provide a definite oil duct in a vertical direction inside the coil.

The radial spacers project out beyond the turns and are covered and held in alignment by channel pieces extending axially the complete length of the coil. The spacer extension, beyond the coil and the covering channels, provides an oil duct outside the coil.

The insulating cylinder between high voltage and low voltage is slipped over the projecting spacers and their channel pieces.

The high-voltage coil spacers are also arranged radially. Each one consists of a hair-pin type spacer

Fig. 3

placed around each coil with the open ends projecting outside the coil. It is formed of a number of parts all locked together, with the base serving to space the coil from the cylinder over which it is assembled.

The spacing of coils from cylinders is such as to provide the necessary extension of insulating diaphragms, placed between each coil to prevent creepage between adjacent coils.

The number of radial spacers in high and low-voltage coils is proportioned to the short-circuit stresses and the strength of the conductors and insulation.

The bracing against axial short-circuit forces of the low-voltage coil consists of a complete ring of bakelized insulating material of the same diameter as the coil, which abuts against the structural steel end clamps at each core yoke.

For the high-voltage coil stack similar rings are used, but in this case fibrous material is not solely depended upon. Engaging with the bakelized end rings at each end of the coil stack are square porcelain blocks, one for each line of spacers. These blocks have holes through them to contain a porcelain locking-pin, which enters the bakelized ring and into bakelized segments, placed between the porcelain blocks and the metal clamps. Adjustment of the clamps is provided by sliding one angle member on the other parts of the clamps, the pressure being maintained by adjustable studs on each clamp and tie rods between the top and bottom clamps. Adjustment in the core window is by means of a bakelized wedge.

The practise is followed in these transformers of bolting the core laminations together rigidly with re-enforcing plates on the outside of the built-up core leg and punching a large square notch at the end of each outer core leg. This notch holds an insulated square bolt which engages with the clamps and thus the core serves also as a tie rod to withstand a part of the short-circuit stresses.

Insulation

In such moderate-voltage transformers the problem of insulating between winding or to ground is not at all difficult. The concentric-winding transformer, of course, lends itself to simplicity of insulation more than any other type. The insulation consists of cylinders of paper, treated with gums and rolled under pressure and at high temperature, forming a dense tough material which has high mechanical strength and a very high dielectric strength, both hot and cold. These cylinders are arranged with suitable oil spaces to form the complete insulation from low voltage to core and from high to low voltage. The insulation of the high-voltage coil stack to the outer core legs consists of sheet insulation with oil spaces. The insulation from the ends of the coil stack has been described under the bracing for short circuit forces.

To reduce the potential gradient on the end high-voltage coil an electrostatic shield, connected to the line terminal of the end, is used between this coil and the core yoke. This shield and the end coil are taped to reduce the potential gradient on the oil surface and to reduce the danger from creepage to the core.

The insulation on the high-voltage conductors consists of a number of thin treated-paper tapes, having extremely high dielectric strength, and it is graded at the end coils so that the end coil will withstand line voltage between turns momentarily. This is for protection against transient voltages. The electrostatic shield connected to the line terminal modifies the distribution of transient voltages in the coil stack and reduces the concentration of voltage on the end coil to from one-quarter to one-third the value it might otherwise attain under conditions of impact of an almost vertically-fronted wave at the transformer terminals.

The electrostatic shields consist of metallic ribbons of high-resistance, wound on an insulating form of slightly less radial width than the adjacent coil. They are taped to give the same insulated radial width. The method of winding is non-inductive to the flow

of the capacitance charging current. High-resistance material is used to avoid appreciable eddy-current loss in the shields, due to the high density of the leakage flux between windings.

Between each high-voltage coil is a pressboard diaphragm with an oil space between it and the coils, as protection against transient voltages. The oil spaces alone are much more than necessary to withstand the normal voltage existing between coils, due to the large number of coils and the few turns in each coil.

The pressboard diaphragm is used instead of merely increasing the oil space, due to the greater energy required to puncture such solid insulation or the time lag of the insulation against puncture by transient voltages.

The taping on electrostatic shield and line coils is additional protection against breakdown between them or the adjacent coils, due to high transient voltages, in addition to the heavier turn insulation on end coils.

The dielectric strength for one minute at normal frequency is equal to approximately line voltage between coils. Under transient stress it is much higher. Between end coils, due to the extra taping, it is much higher yet.

In the low-voltage helical winding the insulation on the conductors is principally to prevent eddy currents between the strands in parallel. The oil space between each turn serves, of course, as a cooling duct and for insulation between turns.

Cooling Arrangements

Special care was used in designing the core to arrange that all surfaces were exposed to the cooling oil. The central core leg is divided into two distinct flux paths with a large duct between them, in addition to which, there are a number of cooling ducts distributed throughout the laminations. The clamps are separated from the core by large ducts to allow the cooling oil access to all surfaces of the core yokes.

The oil for cooling the low-voltage coil is free to pass through these ducts between clamps and core yoke and to pass between the porcelain blocks used to support the high-voltage winding.

The high-voltage winding is exposed directly to the oil in the tank. All coils have an oil duct on both sides and the inside edge. To provide uniform distribution between conductors in parallel, the position of these conductors is transposed. The arrangement of the tap coils in the high-voltage winding is such that this transposition is effective in them.

Due to the large number of conductors in parallel in the low-voltage winding and to the space taken up by the transpositions, it is not possible to obtain perfect equalization of current in all the strands in parallel. This fact is recognized and the average temperature rise of the low-voltage coil, as measured by resistance, is made lower than that of the high-voltage coil so that no strands will exceed the guaranteed temperature rise.

The high-voltage windings were designed to give full kv-a. capacity continuously at any voltage from 36,000/62,300 *Y* to 39,500/68,500 *Y*, without exceeding the guaranteed temperature rise of 55 deg. cent. The rated high-voltage current was thus 611 amperes. The low-voltage winding was designed to carry a current corresponding to 611 amperes on the high voltage on any high voltage connection up to 37,600/65,120. Its rated current was therefore 1915 amperes. At 37,600/65,120 *Y*-volts the transformer kv-a. rating is therefore really 23,000 kv-a. The transformers are also designed to withstand 13,200 volts impressed on the 12,000-volt winding at full load.

Since the dielectric strength of fibrous insulation decreases with increasing temperature, and it is desired to obtain the maximum dielectric strength between end turns and coils, it is essential that these end coils do not attain a higher temperature than the remainder of the windings.

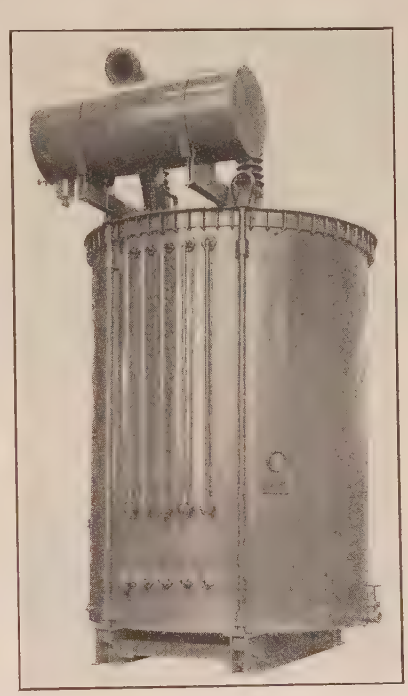

Fig. 4

The cross section of the conductors in the more heavily insulated end coils of the high-voltage winding is much greater than that used in the remainder of the winding, to allow for the increased thermal drop through the extra insulation. Actually the end coils are cooler than the remaining coils.

The temperature rises of a large number of points in the coil, core and clamping structure were calculated and these calculations checked during test by insertion of thermo couples, wherever possible. These tests demonstrated that this type of design is very satisfactory for very large transformers from a thermal

standpoint, as well as from a consideration of ability to resist short circuit stresses and to give great insulation strength.

It was mentioned in the early part of this paper that the design was required to give high efficiency at ⅞ full load. Actually, the efficiency at ¾ and ½ load was found to be slightly higher, as the loss per pound in the core was appreciably lower than the calculated value.

The efficiencies at various loads, based on losses measured by wattmeter at 75 deg. cent. are as follows:

Full load	99.041
7/8 full load	99.083
3/4 " "	99.11
1/2 " "	99.09
1/4 " "	98.67

The average magnetizing current at normal voltage is 2.59 per cent.

The high-voltage taps are connected to a ratio adjuster, operated from an operating handle through an oil tight stuffing box on the cover.

An interesting fact about the construction is the almost complete use of rolled steel. The tank is of cylindrical shape, of steel plate with welded seams with a flat bottom welded in place. It rests upon a structural steel truck with wheels, so that it can be rolled on a standard-gage track. The cast-steel wheels and the manhole covers are the only castings of ferrous metal. The tank cover is a pressed steel plate, with flanges for mounting of bushings, etc., extruded from it.

A cylindrical oil-conservator tank is supported from the tank cover by steel angle supports. The pressure-relief pipe is of welded steel construction and carries a relief diaphragm of glass at its upper end, designed to rupture if the presure in the tank reaches 10 lb. per square inch.

The dimensions and weights of the transformers are as follows:

Height over Bushings	20 ft. 1 5/16 in.
Height over Oil Conservator	16 ft. 11 5/8 in.
Height over Cover	15 ft. 7/16 in.
Inside Diameter of Tank	120 in.
Floor Space over Fittings	12 ft. 10 1/4 in. by 11 ft.
Gallons of Oil	5675
Weight Complete, less Oil	117,800 lb.
Weight of Core and Coils, etc., to be Lifted from Tank	99,000 lb.
Weight of Oil	41,200 lb.
Complete Weight Oil filled	159,000 lb.

For the control of circuits of moderate rating, a new automatic time switch has recently been introduced. The principal feature of the new device is the adoption of a Warren synchronous motor in place of the conventional spring-driven clock commonly employed in other types. The new switch is for use only on alternating current circuits where the frequency is properly regulated.

ELECTRIC VS. STEAM-DRIVEN AUXILIARIES FOR SHIPBOARD

COMPARATIVE COSTS OF OPERATION

An article by Mr. A. H. Jansson in the Marine Review for April 1924 gives some very interesting data as to the comparative costs of operation of a motorship and a turbine driven vessel of practically the same tonnage and characteristics.

The final summary shows the anticipated cost of operation of both ships for the same service results in an annual cost of operation for the steam driven vessel of $103,920 as against $40,780 a reduction of about sixty per cent in favor of the motorship.

A principal item of saving is from the more economical operation of the electrically driven auxiliaries of the motorship as compared with the steam driven auxiliaries on the turbine vessel, the saving being pronounced in the cost of fuel supplied in port, representing a reduction of over fifteen thousand dollars per annum.

A similar saving may be generally expected by the substitution of electrical auxiliaries for the existing steam driven units on shipboard.

DIESEL-ELECTRIC DRIVE FOR GREAT LAKES DREDGE

The first commercial, privately owned Diesel-electric hopper dredge will be put into operation on the Great Lakes by the Construction Materials Company of Chicago during the present year. Orders have been placed for complete electrical equipment to be installed in the LAKE WEIR, which will be converted for this purpose.

The propulsion equipment consists of two 600-brake-horse power Diesel engines, each direct-connected to a 400-kw. main generator and a 35-kw. auxiliary generator. Under normal operating conditions each main generator will drive a 500-h. p. motor direct-connected to a propellor, the craft being of a twin-screw type. Ward Leonard control will be used, providing independent control of each propelling motor and arranged for operation from either the pilot house or engine room. Provision will also be made for operating both propelling motors from one generator.

One auxiliary generator will furnish excitation for the motors and generators and the other will be used for furnishing power for driving the engine room auxiliary motors, steering gear and lighting. All the auxiliaries will be electrically driven.

In addition to the propelling equipment, there will be provided two 400-h. p. motor-driven dredging pumps. The power for these will be taken from either or both of the main generators. Under one condition of operation, both dredging pumps will be driven from one generator, the other generator furnishing power for propulsion. Under another condition of operation, when no propulsion is required, each dredging pump will be connected to a main generator and will operate independently.

Recent Developments in Hydroelectric Equipment

BY WILLIAM MONROE WHITE
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OUR times in this century have often been referred to as the Age of Power. The interest now shown in hydroelectric developments almost justifies our renaming the present age "The Hydroelectric Age."

Remarkable industrial growth has occurred in several sections of our country which have had available cheap hydroelectric power.

The Alabama Power Co., conceived by broad-minded men and nurtured by far-seeing capitalists, is seeking to serve the people of the state of Alabama and adjacent sections, and to provide the very sinews by which the energetic and forehanded business men, within the range of its spreading transmission lines, may develop and establish businesses and industries which will mean prosperity and better living conditions for all. One unit in this great plan of development has recently been placed in regular operation at Mitchell Dam on the Coosa River. For one who is familiar with the hydroelectric developments of North America and who has an appreciation for the genius of those who conceive and build such properties, it is inspiring to stand upon the wooded hills, overlooking the site of Mitchell Dam, and to view the manner in which men have fashioned a mountain of concrete between abutting hills, in combination with foundations, waterways, backwater suppressors, superstructure and buildings for housing the hydroelectric machinery, and yet all

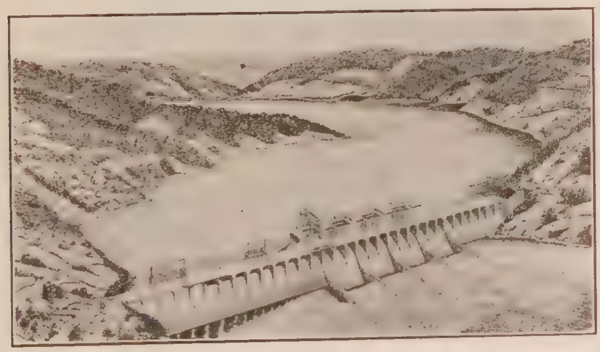

FIG. 1

so devised within the narrow limits of the river's channel at this point, so that no serious obstacle is interposed to the passing of floods which frequently deluge the basin drained by the Coosa River.

The main purpose of this paper is to present to the engineers some facts relating to recent developments in hydroelectric machinery, such as that installed at the power house at Mitchell Dam for economically producing power from falling water. There are installed and now in operation at Mitchell Dam three waterwheels designed and built by the Allis-Chalmers Mfg. Co. of Milwaukee, Wisconsin, each of a capacity of 24,000 horse power when operating under a head of 70 ft., and running at a speed of 100 rev. per min.

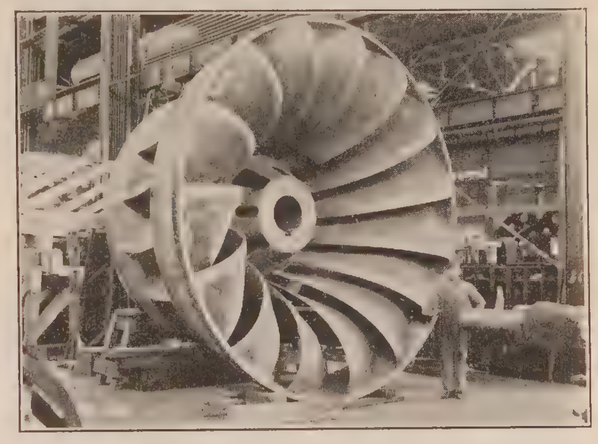

FIG. 2—IRON RUNNER—WEIGHT 105,000 LB. ALABAMA POWER CO. MITCHELL DAM PROJECT

Each of these units is installed in a structure located on the upstream side of the dam, fashioned with waterways of ample capacity, leading to and from the turbine and with walls that support the superstructure. The waterwheels must be located near the level of the tailwater. The generator and electrical equipment are desirably located above the elevation of high water upstream from the dam. This necessitates a considerable distance between the waterwheel and the generator. Notwithstanding this unusual requirement, wheels of normal rational design have been incorporated in the plant each having a single runner of cast iron, 130 in. in diameter weighing 100,000 lb. This runner is shown in Fig. 2. Fig. 3 shows the shop assembly of the cast iron speed ring and movable cast steel guide vanes for one of the units. Each unit is equipped with outside operating mechanism controlled by cylinders located at the bottom of the pit, and operated by governor actuators located on the generator floor.

The main shaft, 25 in. in diameter of forged steel hollow bored, is divided into three lengths and has a total length of 80 ft. The governor flyballs are direct-connected to this shaft and control the governor actuator by means of a connecting rod. Each governor

Presented at the Spring Convention of the A. I. E. E., Birmingham, Ala., April 7-11, 1924.

actuator is supplied with oil by a rotary gear pump with a capacity of 150 gal. per min. at 150 lb. pressure.

The turbine pit can be reached either by an elevator or by a stairway. The elevator is located between the turbines in a vertical shaft which opens into a horizontal tunnel connecting the three turbine pits.

The Thurlow backwater suppressor[1] installed for the first time, utilizes flood water to increase the head on the turbines. The units have been thoroughly tried

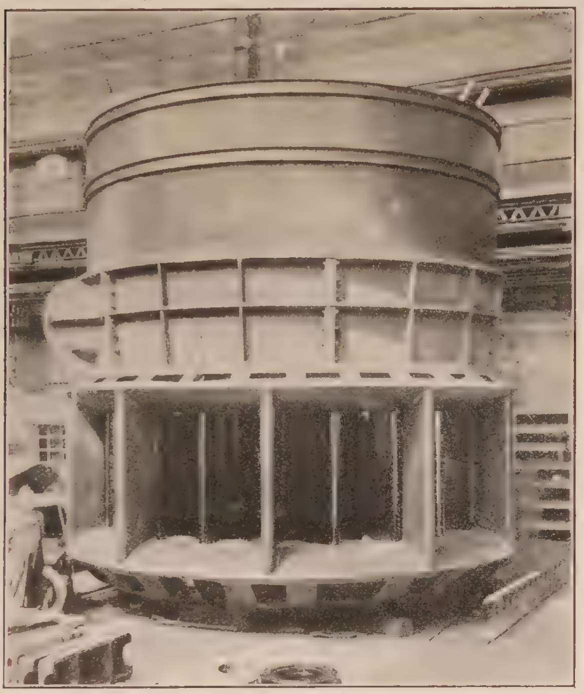

FIG. 3—CONCRETE SPIRAL CASED TURBINES

out and the backwater suppressor greatly exceeded expectations. Another feature is the outdoor gantry crane and the sliding roof of the power house covering the generators. Two of the units are equipped with the White hydraucone and one with a flattened elbow draft tube. The hydraucone is a concentric form of draft tube which changes the direction of flow of water discharged from the runner in a very short length of tube and at the same time regains energy by changing velocity head into pressure head, with very small losses, due to the fact that it is formed to correspond to the natural shape of a jet of water striking a flat plate or a cone. The engineers of the Alabama Power Company were instrumental in having a large number of comparative draft tube tests made, the report of which was read at the January A. S. C. E. Meeting. It is interesting to note that these tests made by disinterested engineers showed the superiority of the hydraucone type of tube over the elbow type. The writer has advocated this design since 1916.

Recently the first of three 70,000-horse power hydroelectric units was placed in operation at the plant of the Niagara Falls Power Company on the American side at Niagara Falls, New York. It is estimated that the operation of this one unit will release for other duties approximately 1500 men daily, who heretofore had been engaged in mining, hoisting, loading, hauling, switching and firing coal under boilers in order to develop this same amount of energy. Fig. 4 shows a sectional view of the 70,000-horse power combined hydroelectric unit which the Allis-Chalmers Mfg. Company now has under construction for the Niagara Falls Power Company for Station No. 3-C. Two of these turbines are of the Wm. Cramp & Sons manufacture, two of the generators are of the General Electric manufacture and the third complete unit, turbine, governor and generator is of the Allis-Chalmers manufacture. Probably a brief description of these, the largest power-producing units in the world, will further serve to give a general idea of the present day trend in the field of hydroelectric development.

The water for these units is conducted from the forebay at the top of the cliff through butterfly valves connected to concrete lined tunnels driven through the solid rock. At the lower end, a plate steel section of penstock is imbedded in the tunnel and 21-ft. 6-in.-

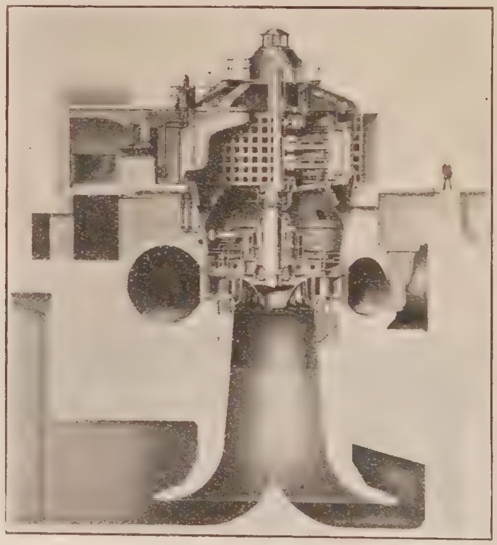

FIG. 4—LARGEST POWER GENERATING UNIT FOR NIAGARA FALLS POWER COMPANY

diameter Johnson type valves are used for shutting off the water from the turbines. The casings on two of the turbines are of cast steel made in sections and bolted together. The third unit is of the circular-section plate-steel type riveted to a cast steel speed ring made in sections. The turbines operate under 213 ft. effective head at 107 rev. per min.

All three units will be equipped with the concentric type of draft tube regainer of the hydraucone or Moody spreading type. The principal features of the Allis-Chalmers hydraulic turbine are a cast steel runner

1. J. A. Sirnit's Paper on "Hydroelectric Power Plant Design" in A. S. M. E. *Transactions*, 1922, Vol. 44.

made in one piece approximately 180 in. in diameter, weighing about 100,000 lb.; a main shaft 34 in. in diameter of forged steel, hollow bored, provided with forged flanges on both the upper and lower end, the runner being bolted to the lower flange with steel-fitted bolts and a main turbine guide bearing of the adjustable, lignum-vitae type, lubricated with water drawn from a settling reservoir at the top of the cliff. The guide bearing is built with four adjustable shoes so that they may be taken up in any direction to compensate for wear. The guide vanes are of cast steel with upper and lower stems cast integral. The upper stems extend through bronze bushings in the cover plate where they are connected to the shifting ring by means of levers and breaking links. These breaking links are so designed that they will give way either in tension or compression when some obstruction prevents the opening or closing of the guide vanes.

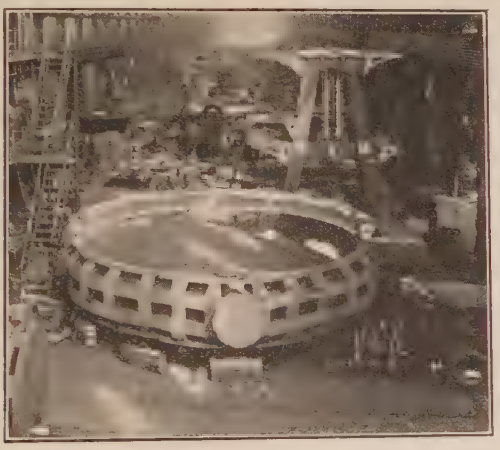

Fig. 5—Butterfly Valve. Assembly of Housing Wicket and Operating Shaft

The generators are rated 65,000 kv-a., 13,200-volts, 25-cycle. The rotors are of cast steel built up in sections with pole pieces bolted to the rim. An auxiliary generator of 650-kw. capacity is mounted within the generator just above the main rotor. This is to provide current for the auxiliary apparatus such as oil pumps, motor-generator sets, cranes, lights, etc. The entire rotating weight of over 700,000 lb. is carried on the Kingsbury thrust bearing. The exterior design of all three generators is practically identical in order to preserve uniformity, although the design of the coils and winding is made independently by the engineers of the General Electric Company and the Allis-Chalmers Mfg. Company.

At the upper end of the penstock, instead of the customary type of square head gate, three 23 ft. 6 in.-diameter butterfly valves are used to shut off the water. They have cast iron housings made in sections and cast steel and plate steel wickets turning on forged steel pivots. The axes of the butterfly valves are set vertically, the operating mechanism being located on the deck above the water level. These valves, which establish a new record for size, are to operate under a head of about 50 ft. Figs. 5-6 show different views of the valves being assembled in the shops of the Allis-Chalmers Mfg. Company.

The largest single contract ever placed for hydraulic machinery is that recently placed by the Quebec

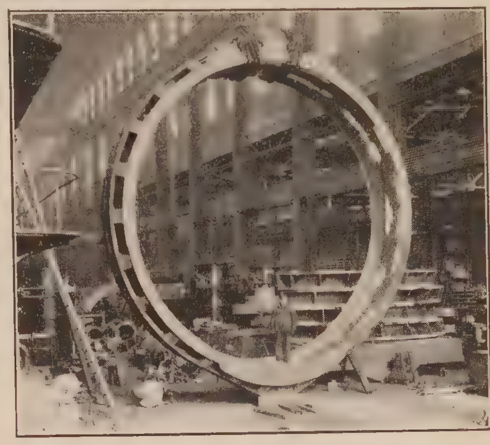

Fig. 6—Butterfly Valve Housing

Development Company covering eight complete 45,000-horse power turbines to operate under 110 ft. head, at 112½ rev. per min., to be installed near Lake St. John in the Province of Quebec, on the Saguenay River, about 125 miles due North of the City of Quebec. The major parts of four additional units are also being installed so that the final power house will consist of 12 units of a total capacity of 500,000 horse power. These units will be of the plate-steel spiral-cased type. Fig. 7 shows a view of the first one of the 12 gigantic casings being erected in the Toronto shops of the Canadian Allis-Chalmers Limited. The inlet diameter is 20 ft. The plate thickness is ⅞ in. at the inlet

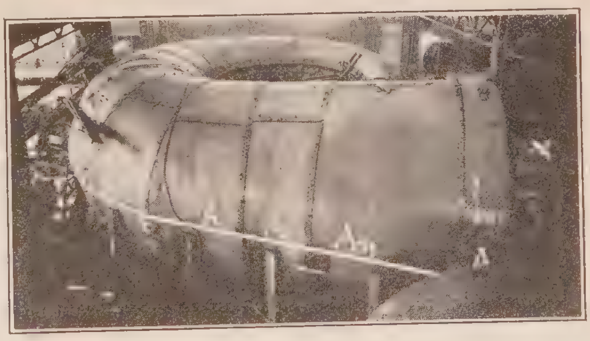

Fig. 7—Plate Steel Circular Section Spiral Casing. One of Twelve 40,000 H. P. Single-Runner Vertical Shaft Turbines for Quebec Development Co., Ltd.

tapering down to ½ in. at the smaller end of the casing.

The past year has seen advances not only in the larger sized hydroelectric units, but even the 200 and 300-horse power open-flume turbines have been improved because of the knowledge gained in constructing larger units. The high-speed Nagler type of runner

is being adopted almost universally, improvements in efficiency having been obtained which make it compare very favorably in that regard with the slower-speed Francis type of runner which it replaces. This, when taken in combination with the improved efficiency of the higher-speed generator at lower cost gives it a distinct advantage. Because of its higher speed, the energy remaining in the water discharged from these runners represents a large percentage of the total. For this reason the design of the draft-tube regainer must be considered carefully. Many tests have been conducted to determine the type of draft tube that will give the best performance with these runners. Frequently the available space, especially in reconstruction projects, is very limited, but wherever conditions allow, we find that the most efficient results are obtained with the concentric or hydraucone type of regainer. Fig. 8 shows a number of high-speed runners being manufactured in the shops of the Allis-Chalmers Company at one time during the past year.

The plate-steel built-up guide vanes used with these

Fig. 8—Nagler High-Speed Runner of Various Sizes, Types and Characteristics for Low Head Developments

high-speed runners have been found to be a distinct improvement. In several cases sticks or pulp wood have become lodged between the vanes distorting the plates considerably. If the old type of cast iron vanes had been used they would have been broken, but with the plate steel construction it was only necessary to remove the damaged vanes and straighten them.

The design of the concrete spiral-casing type of machine has received its share of attention and much time and thought have been expended in improving and simplifying their construction. The writer is in favor of placing the nose of the casing even with, or down stream from, the centerline at the side of the unit. This shortens the path of the water, enables the units to be placed closer together and provides additional thickness in the separating walls between the units where it is most needed. Great care must be exercised in constructing the concrete spiral casing and a large amount of reinforcing steel must be used to properly strengthen it, especially above 60 ft. head. For this reason the writer has long recommended the use of the plate-steel spiral casing for heads as low as 50 ft. For normal settings very little more steel is required to build the spiral casing than is used for the reinforcing of the concrete spirals. It can be readily put together in the field and mass concrete poured around it, doing away entirely with the complicated wooden forms which must be built by expert carpenter or pattern makers. Since the plate steel casings are entirely self-supporting, they may be left practically uncovered. They may be set one almost touching the other, thus decreasing the power house length and doing away with the heavy concrete dividing wall which is necessary with the concrete spiral setting to obtain sufficient strength in case one unit is drained while an adjacent one is in operation. Our Company has constructed plate steel spiral casings for heads as low as 30 ft., and probably established a record for high-head plate-steel spirals during the last year in those built for the New England Power Company, Davis Bridge Plant, developing 19,500 horse power each under 345 ft. head.

A striking example of the use of the plate-steel spiral casing for medium heads is the 20,000-horse power unit for the West Kootenay Power and Light Company to operate under 70 ft. head. In this case, the saving by shortening the distance between the centerline of units, thus decreasing the amount of excavation in the solid rock required for the power house practically paid for the additional cost of the plate steel casing, not taking into account the saving in reinforcing steel and labor in building the forms and constructing the concrete casing.

In the high-head field, undoubtedly, a new record has been established in using a Francis type of turbine for 850 ft. head, these being the Oak Grove turbines of the Portland Railway, Light & Power Company now being constructed by the Pelton Company, where they will use the Moody type of draft tube and rubber sealing rings on the runner and guide vanes.

Impulse turbines have apparently established no new records during the past season, although an additional 30,000-horse power turbine, recently designed and constructed by the Allis-Chalmers Mfg. Company is now being installed in the Caribou Plant of the Great Western Power Company. This is the world's record both for horse power and size of machine, for this type of unit. Experiments conducted in the hydraulic laboratory of our Company upon several different designs of buckets and impulse wheel settings, have proven conclusively that the efficiency of a well-designed impulse unit compares very favorably with that of the best type of Francis wheel and even surpasses it at part gate.

Governors

No radical changes have been made in the fundamental features of hydraulic turbine governors during the last ten years, although many improvements have

been made with the view of simplifying and making this equipment more reliable. The governor equipment for the 70,000-horse power Niagara Falls turbine is similar to that used with the 37,500-horse power units installed in 1919. The flyballs are mounted directly on the main shaft and their motion is transmitted to the governor stand located on the upper generator floor. A large number of plants have been placed in operation, using a motor to drive the flyballs, thus doing away with jack shafts and belts. Fairly satisfactory results have been obtained, although there is always danger of losing the driving current in case of trouble with the generator, in which case the turbine gates will open wide instead of closing. To eliminate this danger a small independent generator mounted on the waterwheel shaft driving only the flyball motor would be ideal, but the cost makes it prohibitive for general use.

In the large power systems existing at the present time, the instantaneous load fluctuations reach such a small per cent of the total output of the system, that there is little actual work for a governor. Their existence is only justified as a safety device, for in case of electrical trouble they will shut the machine down quickly. An interesting development has been the installation of several hydroelectric units not equipped with governors. The generators and oiling systems were designed to withstand prolonged runaway, the units delivering current into a fairly large power system, and regulation being provided by the governor-equipped units in other stations on the system. Sufficient leeway is maintained in the governor-equipped station to pick up any rapid increase in load, slow fluctuations being controlled by manual adjustment of the units not equipped with governors. The three 5500-horse power, 65-ft. head, vertical units of the Brown Company at Berlin, New Hampshire, are the best examples of a complete installation without governors.

Automatic Equipment

Automatic-control equipment for hydroelectric installation has drawn more and more attention during the past few years. We give below the principal functions which the various types of automatic equipment furnished with our governors perform.

Emergency Stop Device

This is a safety feature which is being used on nearly all of the large installations and enables the operator at the switchboard to shut the turbine gates and stop the machine quickly without requiring the assistance of the second or third operator. This is accomplished by closing a switch on the switchboard, energizing a solenoid mounted on the governor stand, which immediately causes the pilot valve to be lifted into the closed position and held there, thus bringing the turbine gates to the full closed position in the minimum time allowable. This emergency stop device may also be connected to temperature indicators in the turbine or generator bearings, or generator windings, to overload or differential relays, or any other recording or indicating device used to indicate abnormal conditions.

Remote-Control Equipment

This equipment is designed to be used with large units where it is especially desirable to have the machine under the direct control of the switchboard operator, even during starting up and stopping, instead of having the second operator start the machine and bring it up to speed by hand as is the common custom. By means of the electrically operated synchronizing device and remote-control load-limiting device the switchboard operator may open the gates slowly and bring the unit up to speed from dead stop, indicatng instruments on the switchboard showing him at all times the exact position of the turbine gates and the load-limit setting. With this equipment it is not necessary for the second attendant to touch the governor and the unit may be separated from the line, shut down completely and the brakes applied by the switchboard operator. This same equipment may be used for controlling a distant unit from another station, although it will require more connecting wires between the two stations than with the full automatic control equipment.

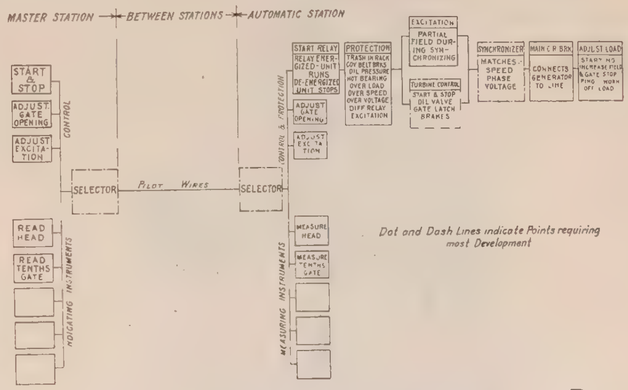

Fig. 9—General Scheme of Complete Automatic Remote Control System

Full Automatic Control

The most general type of automatic remote control is illustrated by the chart shown in Fig. 9. The features which are present at the master station are shown at the left of the sheet. They consist of the control switches by which operations are performed at the automatic station, indicating instruments which show conditions existing at the automatic station, and a selector mechanism by which these various functions can occur without an excessive number of pilot wires between stations. Pilot wires connect the two stations.

The right half of the diagram shows the equipment at the automatic station. Two types of operations are controlled by the selector. The upper part of the diagram shows those required to control and protect

the unit. The lower part shows the measuring devices which work in conjunction with the indicating instruments at the master station.

In any system power is required at the automatic station before it can be started, so that either the incoming lines must be energized or a storage battery provided.

Operation

Consider the method by which the system operates. To start, the selector at the master station is set by hand or by float to the start position and the starting switch closed. In response, the starting relay at the automatic station picks up. If the protective devices indicate that the machine is in running condition, the turbine starts and the alternator is then synchronized and connected to the line. The time required for starting is one or two minutes.

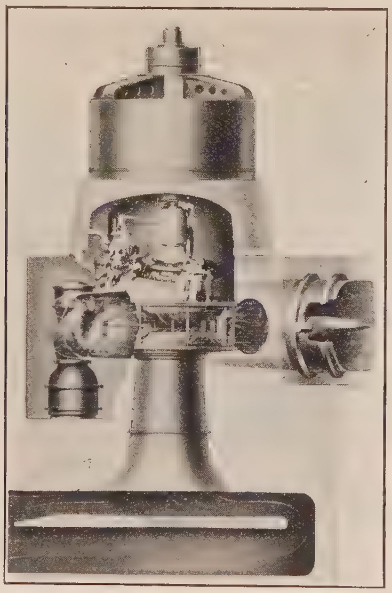

Fig. 10—Sectional View of Hydroelectric Unit, Showing Butterfly Valve, Pressure Regulator, Hydraucone and Integral Type Governor

If desired, equipment may be furnished for adjusting the turbine gates by means of the load-limiting device arranged for remote control. The usual indicating instruments are for head and gate opening but others may be added if desirable.

Power Houses

For the larger type of vertical hydroelectric unit, the one-floor station shown in Fig. 10 seems ideal. The butterfly valve with sealing rings shuts off the water at the inlet of the casing. A governor-actuated pressure regulator prevents excessive pressure rises, due to the use of a long penstock. The plate-steel spiral casing is riveted to a cast-steel speed ring. The governor is of the integral type with the flyball mounted directly on the main shaft and the governor stand located on one of the regulating cylinders, thus doing away with long runs of piping. The generator is supported on a concrete barrel and there is only one floor in the power house, so that one attendant may watch both the electrical and governor equipment. The unit is equipped with the White hydraucone, which type of draft tube has become very popular in the last five years.

From 1911 to 1916 we made a large number of experiments on various types of draft tubes, particularly the hydraucone with runners covering a wide range of specific speeds. Between the years 1913 and 1918 we were developing and improving the Nagler high-speed runner. The insistent demand at that time for higher speeds under low heads was responsible for the rapid advances made in its design. Following this, we made simplifications and improvements in control equipment, including direct-connected flyballs, integrals governors, remote control for butterfly and gate valves, and sealing rings to prevent leakage through butterfly valves.

Recently we have been directing our attention to power house arrangement. The increasing size of units, and the high cost of trained operators have greatly influenced the modern power house design. Every power house arrangement is studied with a view to greater accessibility, increased convenience and the least number of operators. Thus it is necessary to make many changes but with each change are embodied a greater simplicity and sturdiness of design.

Hydroelectric power is the most important source of energy this country has at the present time, so let us give to its proper development the time and thought which it deserves.

POWER DEVELOPMENT AT CAMERON'S FALLS

In December 1920 and March 1921 there were placed in service at Cameron's Falls on the Nipigon River two 10,600-kv-a. 12,000-volt vertical generators driven by water turbines rated at 12,500 h. p. at 72 ft. head. The voltage was stepped up to 110 kv. by three 8000-kv-a. transformers and energy transmitted approximately 80 miles to Port Arthur where the voltage was changed to 22 kv. by means of three 4000-kv-a. transformers. In 1921 energy was delivered at 110 kv. to a paper mill at Nipigon about 12 miles from the generating station.

Installation is now in progress for two more turbo-generator units at Cameron's Falls with a second bank of 8000-kv-a. transformers, a second line to Port Arthur, a second bank of 4000-kv-a. transformers there, and a 110-kv. line to Fort William to supply energy to another paper company.

Estimates have been made for units 5 and 6 and it is expected that the construction work for these units will be proceeded with as soon as the work is completed for units 3 and 4.

Cable Charge and Discharge

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Review of the Subject.—*Conductivity determinations of insulating materials, and therefore the determinations of the leakage resistance of a cable, condenser or similar structure, have always been more or less unsatisfactory, due to a phenomenon often called "soaking in of the charges."*

In general, if a constant direct voltage is impressed upon a circuit, in the first moment large transient currents flow, representing the energy storage and adjustment in the magnetic and dielectric fields of the circuit. These transient currents however vanish very quickly, usually in a very small fraction of a second, and all the currents in the circuit or circuits then become constant. If a constant direct voltage is impressed upon a cable or similar structure, large transient currents also flow momentarily; but after these currents of energy adjustment in the electromagnetic field of the system have vanished, usually after a small fraction of a second, the remaining current is not constant, as in the usual electric circuit, but continues to decrease slowly, for minutes or even hours. If then the cable is discharged by short-circuiting it, after the large initial transient discharge current has passed and the voltage on the cable has become zero—in a small fraction of a second—the current coming out of the cable does not entirely vanish, but a small discharge current continues to flow for many minutes or even hours. Or, if the cable has been discharged by short-circuiting it for a short time, until its terminal voltage has become zero, and the short circuit is taken off, a terminal voltage and an electrostatic charge gradually build up again at the cable, reach a maximum after some minutes, and then gradually decrease again.

Various explanations have been proposed of this phenomenon as a hysteresis effect of the dielectric, etc.

It is shown in the following, that this phenomenon of the "soaking in of the charges" or the "electrification of the cable" is a true electric circuit transient, has nothing to do with hysteresis effects, but is the result of, and explained by the energy adjustment of a system with constant values of resistance, inductance and capacity, that is, is in no essential different from the usual rapid starting or stopping transient of the ordinary circuit, except that it is many thousands of times slower. This great slowness is due to the fact that the resistance in the transient circuit is the leakage resistance of the cable dielectric, and therefore extremely high, measured not in ohms but in hundreds of megohms.

If the dielectric of the cable consists of two or more materials, having different resistivities, or different specific capacities, or both, then the distribution of voltage through the dielectric gradually changes. At the moment of voltage application, the voltage distributes between the component dielectrics in proportion to their specific capacities; gradually however this voltage distribution changes to a distribution proportional to the resistivities of the component dielectrics, and electrostatic charges build up in the interior of the dielectric, at the boundaries between the component dielectrics. The electric quantity has to be conducted through the dielectric, and due to the very high resistivity of the dielectric, this energy readjustment within the dielectric occurs with extreme slowness, giving a transient of a duration of many minutes, but a true electric transient nevertheless, like the usual transients of a duration of milliseconds.

In the discharge of the cable, the reverse occurs, and the internal charges gradually disappear by conduction through the dielectric.

This phenomenon is discussed in its various aspects, and the equations of the slow transient derived, in the following:

It is shown that this slow transient always is impulsive or exponential, and consists of (n—1) terms, if the insulation is composed of n materials.

A number of conclusions are derived, some of which may be pertinent with regard to the mechanism of breakdown of insulation.

By this slow transient, the energy stored in the cable as condenser increases. Its apparent capacity increases. The conduction current, and therefore the $i^2 r$ losses in the dielectric, are much larger with alternating than with direct voltage. The distribution of dielectric stress between the component dielectrics changes and this may give a different dielectric strength for alternating voltage—at which the initial condition of stress distributions is permanent—and for direct voltage. Also, a time lag of insulation breakdown may result, which is not a temperature or deterioration effect. Under certain conditions, there may occur a negative time lag, that is, a condition where the insulation stands higher voltages when slowly and continuously applied than when rapidly applied for a short time.

CONTENTS

I. Physical Consideration

1. Cable Charge

If an ideal condenser, that is, a condenser having constant capacity, $C = \frac{1}{k}$, and no losses, is connected to a source of alternating voltage, e_0, over a circuit of constant resistance, r_0, and constant inductance, L_0, it takes a charging current, which leads the terminal voltage by 90 degrees. This charging current does not pass through or into the dielectric of the condenser, but is limited to its terminals. It is preceded by a transient immediately after closing the circuit. This charging transient is oscillatory, if the circuit resistance r_0 is below, and is impulsive, if the circuit resistance is above the critical value $2\sqrt{\frac{L_0}{C}}$. This transient charging current usually is much larger than

Abridgement of a paper presented at the Annual Convention of the A. I. E. E., Swampscott, Mass., June 26-29, 1923. Complete paper available without charge to members on request.

*Deceased.

the permanent alternating charging current, and usually vanishes in a small fraction of a second.

If the impressed voltage is continuous, the same starting transient occurs, but with its disappearance, after a fraction of a second, the current at the condenser terminals vanishes and the condenser acts as an open circuit on the continuous supply voltage, if the resistance of the dielectric of the condenser is really infinite.

If however the dielectric of the condenser has a finite, though very high, resistance r, at continuous impressed voltage e_0 the starting transient dies down not to zero, but to a finite limiting current $i_0 = \frac{e_0}{r}$. With an alternating impressed voltage, the charging current then does not lead the terminal voltage by exactly 90 degrees, but slightly less, and therefore contains an energy component of current i_0'. This energy current, though small compared with the total charging current, usually is larger than the conduction current i_0 which passes through the dielectric with a continuous voltage, as it represents not only the conduction through the dielectric, but also the losses in the dielectric due to the alternating field, of the nature of a dielectric hysteresis, etc.

This applies to an ideal condenser, that is, a condenser with perfectly uniform dielectric.

Tests show that in a real condenser, such as a cable, with a continuous impressed voltage e_0, the current remaining after the passage of the starting transient that is, after a fraction of a second, usually is not the conduction current $i_0 = \frac{e_0}{r}$, and is not constant, but is larger than i_0, often many times, and gradually but slowly decreases, for minutes and even hours, approaching the conduction current i_0. There is thus a passage of current through and into the dielectric, for a considerable time. This often is expressed as the "soaking in" of current or of charge.

The resistance of the cable insulation therefore cannot be measured by impressing a continuous voltage and reading the current, but constant voltage has to be kept on the cable until the current has become constant. Usually this is expressed by saying that the cable has first to be electrified.

2. Cable Discharge

A similar difference occurs between the ideal condenser and the cable in the discharge.

If an ideal condenser, charged to terminal voltage e_0, is discharged by short-circuiting its terminals, the discharge transient passes, usually within a fraction of a second, current and terminal voltage drop to zero and the condenser is dead. In a real condenser, as a cable however, after the passage of the discharge transient a small discharge current continues to flow, gradually decreasing, for minutes and even hours. Furthermore, if after the external discharge transient has passed and the terminal voltage dropped to zero, that is, after a fraction of a second (and usually also still after several seconds) the circuit of the cable is opened, the terminal voltage does not remain zero, but a terminal voltage reappears and gradually rises, for minutes, and corresponding charges build up on the condenser terminals, until a maximum "residual voltage" and "residual charge" has accumulated; then voltage and charge again decrease and finally vanish, often after many minutes or even hours. This residual charge may be quite considerable, sufficient to give dangerous shocks.

This phenomenon in the charge of a condenser, of the soaking in of the current and the formation of residual charges and residual voltages after discharge, does not seem to occur when the dielectric of the condenser is perfectly homogeneous, but is very pronounced when the dielectric is a composite of different materials of different electric characteristics (resistivity and specific capacity), especially if the structure of the dielectric is laminated, as in a cable.

This phenomenon is not always fully understood, and various attempts have been made to explain it as an effect of dielectric time lag, or as the result of a change of the specific capacity with time and voltage, as a hysteresis effect, etc. This is not so however, but it is a true circuit transient, as will be seen in the following, that is, a readjustment of the stored electric energy to changed circuit conditions, at constant values of circuit constants, r and C. It has nothing to do with hysteresis or time lag. The great interest of this slow transient consists in its very long duration, sometimes reaching into hours. This makes it many thousand times slower than the external condenser transient.

In a condenser with composite dielectric, like the laminated dielectric of the cable, energy storage occurs —and therefore results in transients at a change of circuit conditions—in the dielectric, at the boundaries between different dielectrics. This energy must be conducted over the resistance of the dielectric, and as this resistance is extremely high, the duration of this "internal transient," that is, "transient of internal energy readjustment," must be very great, compared with the duration of the "external transient," in which latter, the energy readjustment occurs over the resistance of the external or supply circuit; the latter resistance is measured in ohms; that of the internal transient in hundreds of megohms.

This great difference in duration, between the external transient of readjustment of terminal voltage to changed circuit conditions, and the internal transient of readjustment of internal charges within the dielectric, makes it possible to separate the two types of transient and treat them separately.

The external transient has passed and vanished, before the internal transient has appreciably started. Therefore, in dealing with the internal transient, the

external transient may be considered as non-existent, but the final circuit conditions brought about by the external transient (constant terminal voltage e_0) considered as the initial circuit condition for the internal transient. Inversely, when dealing with the external transient, the internal transient may be considered as non-existing, that is, its initial circuit condition considered as permanent.

Approximate magnitudes of the quantities are, for a 12,000-volt, 2-mile, 60-cycle, 3-phase cable at 20 kv. continuous impressed voltage:

External transient: 25 amperes, 240 cycles.

Duration of external transient: 0.005 sec.

60 cycles charging current: 5 ampere maximum.

Energy component thereof: 0.2 amperes.

Initial value of slow transient: 0.37 to 2.4 milliamperes, depending on age and temperature.

Final value of slow transient: 0.11 to 1.28 milliamperes, depending on age and temperature.

Duration of slow transient: 4 min.

Residual charge: 8 kv.

3. Formation of Internal Charges

Let the dielectric of a condenser be composite, consisting of layers of two materials—as impregnated paper and petrolatum in the cable—of different specific capacities and resistivities.

Let now the circuit be closed and a continuous voltage be impressed upon the condenser. By a rapid external transient, in a small fraction of a second, the terminal voltage of the condenser then becomes constant at the value e given by the supply voltage.

An electrostatic field K thus appears between the condenser terminals giving an electrostatic flux density D in the dielectric between the condenser terminals, and an electrostatic charge Q on these terminals.

At the first moment of terminal voltage e, there can be no electrostatic charge inside of the dielectric, since such charge would have to pass through a part of the dielectric, and due to the very high resistance of the dielectric, it takes a much longer time to conduct such internal charge through the dielectric, than the time required by the external transient to produce the terminal voltage e by supplying the terminal charges Q. Thus in the first moment of terminal voltage e no internal charge can yet exist.

A line of electrostatic flux must either terminate in an electrostatic charge, or continue into infinity or into itself. Since in the first moment of terminal voltage e, or at time $t = 0$, there can be no electrostatic charge inside of the dielectric, no line of electrostatic flux can terminate in the dielectric, and all lines of electrostatic flux therefore must pass through from terminal to terminal, in the first moment of terminal voltage e. That is, the flux density D between the cable terminals must in the first moment be uniform, and the initial voltage distribution between the component dielectrics thus must be such as to give the same flux density. That is, the voltage must distribute between the different layers of the dielectric in proportion to their elastances, that is, the reciprocals of their capacities. That is, the voltage gradient in the two dielectrics must be proportional to the elastivities, or inversely proportional to the specific capacities of these two dielectrics. They would remain so, if there were no conductivity, that is, if the resistance of the dielectric were infinitely high. The transient thus were ended, and no further change occurs.

Due to the finite, (though extremely low) conductivity of the dielectrics, a current is conducted, or "leaks" through the dielectrics, and the current density of this current in the two dielectrics, is proportional to the electrical conductivities of these dielectrics and proportional to the voltage gradients in them. The initial voltage gradients however are proportional to the elastivities of the two dielectrics. The elastivities have no direct relation to the conductivities, and high resistivity may concur just as well with low elastivity, as in sulphur, as it may concur with high elastivity, in air, and inversely. It therefore is obvious that in general the current densities in the two dielectrics would not be equal. They would be equal only if it happened that the conductivities of the two dielectrics are proportional to their elastivities.

In general we therefore find, in the first moment of constant terminal voltage on the cable as condenser with composite dielectric:

All electrostatic charges are on the terminals.

Uniform and equal electrostatic flux density in both dielectrics.

No internal charges in the dielectrics.

Different current densities in the two dielectrics.

Voltage distribution between the two dielectrics by their respective capacities, that is,

Voltage gradients proportional to elastivities.

In general thus, in the initial moment of constant terminal voltage on a cable, the current densities in the two component dielectrics are different. This means that at every boundary between the two dielectrics a discontinuity or change of current density occurs, and more current flows towards the boundary from the one side, than leaves it on the other side. Consequently, an electrostatic charge builds up at the boundary between the two dielectrics, due to the difference between the two current densities on the two sides of the boundary. This electrostatic charge lowers the voltage gradient and thus the current density in the dielectric of higher current density, and raises it in the dielectric of lower current density, and thereby reduces the difference between the current densities in the two dielectrics and with it reduces the rate of building up of internal electrostatic charges on the boundaries between the two component dielectrics, until finally the current densities in both dielectrics become equal and any further building up of internal charge ceases.

The final condition thus is that of uniform current

density in both component dielectrics. That means, the voltage gradients in the two dielectrics are proportional to their respective resistivities, and therefore independent of the capacities or elastivities of the two dielectrics. The electrostatic flux densities are different in the two component dielectrics. Lines of electrostatic flux terminate within the dielectric, at the boundaries between the two component dielectrics, and they terminate in electrostatic charges located at these boundaries.

4. The Slow Cable Transient

Thus there occurs, at constant terminal voltage, a gradual change in the dielectric of a cable as condenser with laminated composite dielectric, from an initial condition immediately after the appearance of the constant terminal voltage at the condenser, until final condition is reached, by a slow transient lasting many minutes and even hours. This consists of:

A change from the initial voltage distribution by capacity, to the final voltage distribution by the resistance of the component dielectrics.

A change from uniform electrostatic flux density and ununiform current density, to uniform current density and ununiform flux density.

The formation of internal charges at the boundaries between the two component dielectrics.

A current passes through the dielectric. This starts at a large value (though small compared with the external transient current) and first rapidly and then more slowly decreases, to a final minimum value of conduction current.

It thus consists of a permanent component, which is the conduction current sent by the terminal voltage through the resistance of the dielectric, and a transient component, by which the terminal voltage supplies the internal charges over a part of the resistance of the dielectric.

The energy of the permanent current is dissipated as heat in the resistance of the dielectric.

Half of the energy of the transient current is stored as the electrostatic energy of the internal charges at the boundaries between the two dielectrics, the other half is dissipated as heat in the resistance of the dielectric, over which the internal charges have to be conducted.

The energy electrostatically stored in the condenser therefore increases during the slow transient of internal charge, that is, of "soaking in of the charges," by half the energy of the transient component of the slow transient, and the apparent or effective capacity of the condenser correspondingly increases.

That is, the energy stored in the condenser, and the capacity of the condenser, reach a maximum at the end of the slow charge, when the conduction current has become a minimum. The stored energy and the capacity are a minimum at the beginning of the internal charge, that is, in the first moment of constant terminal voltage at the condenser. The latter also is the case with an alternating supply voltage, since even at low machine frequencies the duration of a cycle is short compared with the duration of the slow transient, and the internal conditions of the condenser (such as voltage distribution by capacity and not by resistance) with alternating terminal voltage therefore correspond to the initial conditions of constant terminal voltage.

A condenser with composite dielectric thus does not have a constant capacity, but has one value of capacity —the minimum—for instantaneous voltage application or alternating terminal voltage, and another value—the maximum—for continuous voltage application.

A condenser with composite dielectric thus differs from a condenser with uniform dielectric in that in the latter energy is stored as electrostatic charge at the external terminals only, while in the former energy is stored as electrostatic charge in the dielectric also, and this latter energy can be supplied—or withdrawn, in the discharge—very slowly only, as it has to flow over the higher resistance of the dielectric, and thereby gives rise to the slow terminal transient, which often is misunderstood as a hysteresis or lag phenomenon, but is not such, but is a true resistance phenomenon, and as such independent of the frequency, but calculated from the ratio of resistances and capacities of the two component dielectrics.

5. Effect on Puncture Voltage

As seen, at constant terminal voltage, the voltage distribution between the two component dielectrics changes between the initial and the final condition. That is, in the one dielectric the voltage gradient is higher in the initial conditions (and thus with alternating terminal voltage) than in the final conditions, and the reverse is the case in the other dielectric. Suppose now the first dielectric is operated closer to the limit of its dielectric strength. If then the terminal voltage is brought up rapidly, so that the initial condition of internal voltage distribution persists, at a certain terminal voltage the first dielectric will reach its disruptive gradient, and puncture of the insulation occurs. Suppose however, the voltage is brought up very slowly, so that throughout the entire voltage rise the final voltage distribution between the two dielectrics persists. At this final voltage distribution, the voltage gradient in the first dielectric is lower, for the same terminal voltage, and the disruptive gradient in the first dielectric is therefore reached only at a higher value of terminal voltage. That is, in this case a higher value of puncture voltage is required when the voltage is very slowly applied, than when the voltage is rapidly increased. This is the reverse of the usual experience—in general, the more rapidly the voltage is increased, the higher voltage the insulation will stand. However, this phenomenon of a lower voltage being sufficient for breakdown when rapidly applied than when slowly applied, has been repeatedly observed

with composite insulation. In this case, a constant voltage, applied at once, may break down the insulation, while even a higher voltage when very slowly applied, may not damage it—in the former case, the dielectric passes through the initial stage of voltage distribution, where it is overstressed, while in the latter case it has passed this stage at lower terminal voltage, while still below breakdown voltage, and at the higher terminal voltages had relieved itself by the readjustment of voltage throwing a higher gradient on the second and stronger dielectric.

Inversely, if the weaker dielectric is the second one, in which the voltage gradient in the final condition is higher than in the initial condition, then with a rapidly increasing terminal voltage the insulation may show a much higher puncture voltage than with a very slowly increasing voltage, since in the latter case the same terminal voltage gives a higher gradient and thus higher stress across the second dielectric, than the same terminal voltage so rapidly applied that the initial condition persists. In this case, the insulation therefore would show a marked time lag of disruptive strength, while in the above case we may speak of a "negative time lag," that is, slow voltage application increases the disruptive strength.

It is interesting to note that here, in the second case, we get a time lag of breakdown, which is not a temperature effect, but a straight resistance phenomenon, and get it under the assumption that the relation between breakdown and breakdown gradient is instantaneous, that is, that the breakdown occurs as soon as the breakdown gradient is reached.

6. A-C./D-C. Ratio of Puncture Voltage

With alternating terminal voltage the internal conditions of the insulation always are the initial conditions. In the second case, when the voltage gradient increases with the time in the dielectrically weaker material, an alternating terminal voltage would give the same voltage gradient as exists in the initial conditions of a constant voltage equal to the maximum of the alternating voltage, and lower than the final voltage gradient of the constant voltage. Thus, if the breakdown is strictly mechanical, due to voltage stress, and no additional causes of breakdown occur with alternating voltage, then puncture would occur with an alternating voltage of a maximum equal to the constant voltage rapidly applied, but a very slowly applied constant voltage would cause a breakdown at a lower value of voltage than the maximum of alternating puncture voltage. That is, we would get a d-c./a-c. ratio of less than one. While this is against the usual experience it has been observed in a number of instances.

Dominating in the insulation puncture comes in the temperature effect, that is, local temperature rises which materially lower the breakdown voltage. As with alternating voltage energy losses occur, such as dielectric hysteresis, etc., which do not exist with constant voltage, local heating would be greater and the puncture voltage therefore lower with alternating voltage.

Thus there are three different conditions met in a composite dielectric, which have no constant direct numerical relation with each other:

1. Very slowly applied constant voltage, giving an internal voltage distribution by resistance.
2. Fairly rapid constant voltage application, giving an internal voltage distribution by capacity.
3. Alternating current voltage supply, giving the same voltage distribution as 2, but with additional energy losses and heating, the latter depending on the rate of voltage application.

The ratio of puncture voltage, d-c. and maximum a-c. in the three cases, may have any value between less than one and two to three or even more, depending on the relative constants of the two component dielectrics, on time and on temperature, etc., and research in this direction should throw a great deal of light on the mechanism of breakdown.

7. A-C. and D-C. Resistance of Dielectric

With alternating terminal voltage the internal conditions of the composite dielectric are the initial conditions of constant voltage electrification. It follows, that with alternating terminal voltage the conduction current which passes into the dielectric is not the final or permanent value of the conduction current at constant terminal voltage, but is the—usually much larger—initial or transient value of conduction current, that is, the initial value of the slow charging transient, and the $i^2 r$ loss in the dielectric therefore is much larger under alternating terminal voltage, than under continuously applied constant terminal voltage.

Thus, assuming that there were no other losses but conduction losses in the cable dielectric under alternating voltage, that is, hysteresis, ionization, etc., were absent, then the energy component of the alternating cable charging current would be—usually much—larger than the conduction current with constant terminal voltage, and the resistance of the dielectric, from energy current and alternating terminal voltage, would be much lower than the resistance measured with direct current. Nevertheless, the alternating energy current and the resistance calculated from it are a true conduction current and true ohmic resistance effect, and are independent of the frequency, though they are often misunderstood and misinterpreted as time lag or hysteresis effects. As seen, they are ohmic resistance effects of the circuit between the internal charges and the external circuit. In addition thereto occur probably true hysteresis effects, ionization effects in air by ozonization, similar ionization effects in other materials, etc., which are still little understood. Also the effects of moisture and its movement under the dielectric field.

Cable Discharges

Suppose a cable as laminated composite condenser of two dielectrics, is charged to a constant terminal voltage, and stationary conditions of voltage distribution and internal charges reached.

We now short-circuit the cable.

By the rapid external transient it discharges, within a small fraction of a second, and terminal voltage and terminal charge drop to zero. In the first moment, the internal charges, at the boundaries of the two dielectrics, remain the same. These internal charges now discharge their energy—which was half the energy of the slow charging transient, as seen above—towards the cable terminals, through the very high resistance of the dielectric, by a slow transient, a current which starts with a maximum (though very small compared with the external discharge transient) and gradually decreases to zero.

Or we just disconnect the cable from the supply voltage, leaving it open-circuited, but charged. The terminal charges and the internal charges then supply the conduction current, which passes through the dielectric, and current, charges, terminal voltage and internal voltages decrease and finally die out gradually and proportionally to each other, on small exponential transients.

The most interesting case is to discharge the cable terminals by short-circuiting for a short time (a fraction of a second) until the external cable discharge transient has passed and terminal volts and terminal charges dropped to zero, but before any appreciable discharge of the internal charges has occurred, and then to open the circuit again. This leaves the cable with zero terminal voltage and zero terminal charge, but with internal charges at the boundaries between the two component dielectrics, and corresponding internal voltages. That is, by the withdrawal of the terminal charges the internal charges as bound charges are set free and their corresponding voltages appear. These voltage gradients produce currents through the resistance of the dielectrics. These slow transient currents decrease the internal charges and build up external or terminal charges, which appear as terminal voltage. Thus a transient terminal voltage gradually builds up, increases to a maximum and then decreases again and gradually dies down to zero. Of the energy of the internal charges, half is stored as terminal charge giving residual terminal voltage:—the other half is dissipated in the resistance of the dielectric in conducting the charge through the dielectric. Assuming that the energy stored by the internal charge was half the energy of the terminal charges of the condenser. When building up a residual terminal charge, this then would contain half the energy of the internal charges, or one-quarter the energy and therefore half the voltage of the initial terminal charges. Thus a very considerable residual voltage, capable of giving dangerous shocks, may build up on a composite condenser like a cable.

8. Conclusions

In the preceding we have described the simplest case, of a laminated condenser consisting of two different dielectrics, and thus giving rise to a slow transient consisting of one exponential term.

If the condenser comprises n different dielectrics, the slow transient consists of $(n - 1)$ exponential terms, thus is more complex, but otherwise not essentially different. Observation of such slow transients on three-phase cables seems to show that they are not well represented by a single exponential slow transient, but are fairly well represented by the combination of two slow transients, the one being somewhat faster than the other. Such a case is shown in Fig. 1, with the observed currents marked by crosses. It gives three curves of the same cable, for three successive tests at different periods of the year and therefore different temperatures. This would correspond to a composite condenser having three different kinds of dielectric. In a three-phase cable we have impregnated paper as main insulation, petrolatum as impregnating material, and impregnated hemp in the triangular corner pieces between conductors and armor.

Structurally, we have considered a laminated shape, first, because it is mathematically by far the simplest case, and second, because most of the industrially important insulations are laminated; cable, condenser, high-voltage machine insulation, etc. In general, similar relations may be expected to exist in an irregularly unhomogeneous dielectric.

STANDARD WAVEMETERS

To serve as a standard of radio frequency the Bureau of Standards has two specially constructed wavemeters covering the frequencies in more general use from 18 to 4600 kilocycles per second (16,650 to 65 meters). These standard wavemeters are used in calibrating wavemeters belonging to the Radio Inspection Service, manufacturers, colleges or others in need of standards of frequency, in radio measurements and in adjusting the radio transmitting set which is used to transmit standard frequency signals.

Each standard wavemeter consists of a variable air condenser of special design, four fixed mica condensers, a number of interchangeable inductors or coils, and a resonance indicating device. The majority of the inductors are wound with high-frequency cable in a single layer upon a skeleton frame of laminated phenolic insulating material, sometimes called bakelite.

The wavemeter is tuned to a source of radio-frequency currents by varying the air condenser and obtaining the maximum deflection of an indicating instrument which is connected to two turns of wire and loosely coupled to the inductor in the wavemeter circuit. Either of two indicating instruments may be used, a thermogalvanometer or a d-c. milliammeter and crystal detector. The d-c. milliammeter and crystal detector are used when more accurate indications are desired than are possible with the thermogalvanometer.

Electrical Equipment

Consolidated Mining and Smelting Company's Zinc Plant, Trail, B. C., Canada

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Member, A. I. E. E.
Asst. Supt., West Kootenay Power and Light Company, Bonnington Falls, B. C.

Introduction

THE great demand for supplies of zinc required in the manufacture of munitions, especially in the manufacture of brass shells which contain 66.6 per cent copper and 33.4 per cent zinc, led to an investigation in 1915 to ascertain the feasibility of producing metallic zinc in Canada. This resulted in the establishment of a zinc plant by the Consolidated Mining and Smelting Co. of Canada at Trail, B. C., at an initial cost of $2,500,000.

General View Trail Plant

The production of zinc was increased from a daily output of 1000 pounds (453 kg.) to the present production approximately 80 tons (72,500 kg.) daily, having a purity of 99.9 per cent. The present annual capacity of the zinc plant is approximately 29,200 tons (29,500 metric tons). The starting up of the electrolytic plant at Trail and the almost simultaneous starting of one at Anaconda, Montana, and the placing of orders with both of these plants, broke the German strangle hold on high grade zinc, in fact other grades as well.

Until about 1915 all commercial zinc was produced by distillation, a process involving many difficulties. The resultant product was comparatively impure and there was also a very decided factor of loss due to certain peculiar tendencies of zinc vapor to solidify in undesirable forms. Today a great deal of the zinc which is produced in North America is deposited electrolytically; a process which results in a purer and more homogeneous product and therefore, one which is more desirable in the trades than that made in the old way.

It is not the intention of the writer to devote for any length of time on the zinc process as this article is intended to cover only the electrical equipment of the plant. For a complete description of this process the reader is referred to an article by L. W. Chapman in the *Chemical and Metallurgical Engineering Magazine*, August 11th, 1920, Vol. 23, No. 6, pages 227-237.

Power Supply

The power supply is derived from a distributing station located between the two generating rooms. This station being the property of the West Kootenay Power & Light Co., a subsidiary of the Consolidated Mining and Smelting Co. The Power Company is one of the pioneer concerns engaged in hydroelectric development in British Columbia which has played such an important part in the mining development of the Kootenay District, in fact without such power this development would have been impossible.

West Kootenay Power & Light Co. Substation

Power is transmitted to Trail, a distance of approximately 32 miles (51.2 km.) from the company's hydroelectric plant, over two transmission lines at a pressure of 60 kv.

The substation is of solid brick construction, the incoming lines entering through the roof. The interior is subdivided into three sections, namely, transformers, high-tension switches and lightning arresters, and low-tension bus structure with the low-tension switches and control panels.

Electrical Equipment in Distributing Station

The transformers are of the Canadian Westinghouse Company's manufacture, each bank, of which there

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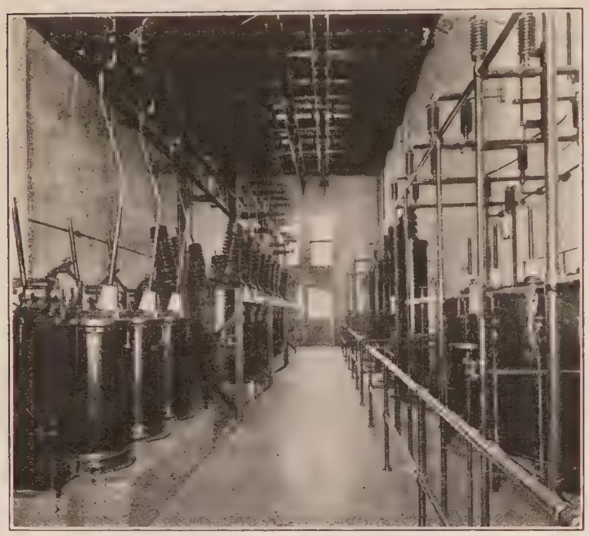
are two, is located in a fire proof compartment and consists of three single-phase, 2500-kv-a. water-cooled, oil-insulated transformers with primary and secondary connected delta. It is to be noted that no spare transformers have been installed. In the event of a transformer breaking down, service would be restored by operating the damaged bank open delta while repairs were being made. Each transformer is mounted on a truck. The high-tension switches on both the incoming lines and transformers are of the Canadian



High-Tension Room, West Kootenay Power & Light Co. Substation

General Electric Company's manufacture; these being their form K-26-70 kv.–300 ampere. These switches are equipped with tank lifters, and are protected through inverse time limit series trips mounted directly overhead on the bus structure.

Two sets of aluminum lightning arresters protect the two incoming lines. Directly adjoining, the high-tension room is the low-tension bus structure which is of concrete. On this structure are mounted all the low-tension switches. Two form *H*-6 connect the secondaries of the transformers to the bus. Eighteen form *H*-3 switches are on the outgoing feeders, connecting the smelter substation and Lead Refinery substation. There are thirteen motor generator feeders and a circuit for lighting the city of Trail. All the switches are protected by time limit overload relays. A d-c. panel is mounted at one end of the control panels from which is operated a 5-kw. 125-volt motor generator set for charging a 60-cell storage battery. This battery energizes the operating bus for the remote control switches as well as supplying an auxiliary lighting source in case of power failure. This is accomplished by a quick throw over switch operated by a no-voltage release. The city lighting system is fed from a 3-phase automatic induction voltage regulator set for 10 per cent boost or buck. The street lights are controlled from a series mercury arc rectifier operating magnetite arc lamp.

Some mention should be made of the two 20-kv. lines passing through this station. Up to the time of building the Zinc Plant, the only lines coming into Trail were the 20-kv. lines feeding directly into the Consolidated Mining and Smelting Company's substation which has now been dismantled. These lines originally fed from No. 1 power house, but as the load conditions very seldom require both plants to be in operation at the same time, these lines are usually supplied from a 20-kv. bank of transformers in No. 2 power house.

In the event of conditions necessitating the operation of both plants, No. 1 plant can be paralleled with No. 2, or No. 2 can drop the load on the 20-kv. lines, leaving No. 1 plant to handle this. Generally No. 1 and 2 plants are operating in parallel through Trail, all phasing being done at the power house. These lines are controlled from Westinghouse Type "G. H." Oil circuit breakers and protected by reverse power relays.

The total maximum demand from this station to date has been 20,900 kw. in other words the equipment has safely withstood an overload of 22 per cent. R. A. Ross, M. E. I. C., Montreal, acted as consulting engineer for the power company.

Low-Tension Room, West Kootenay Power & Light Co. Substation

Generator Rooms

The generator rooms at Trail, although they do not embody any new features, are of interest due to the fact that it is another application of electric power to a new industry. An industry that has sprung up since the commencement of the late war. They are of hollow tile and steel construction. No. 1 Generator Room is 266 ft. (81.1 m.) in length and 30 ft. (9.14 m.) in width. No. 2 generator room is 218 ft. (66.4 m.) in length and 30 ft. (9.14 m.) in width. The floor and foundations of the motor generator sets are solid

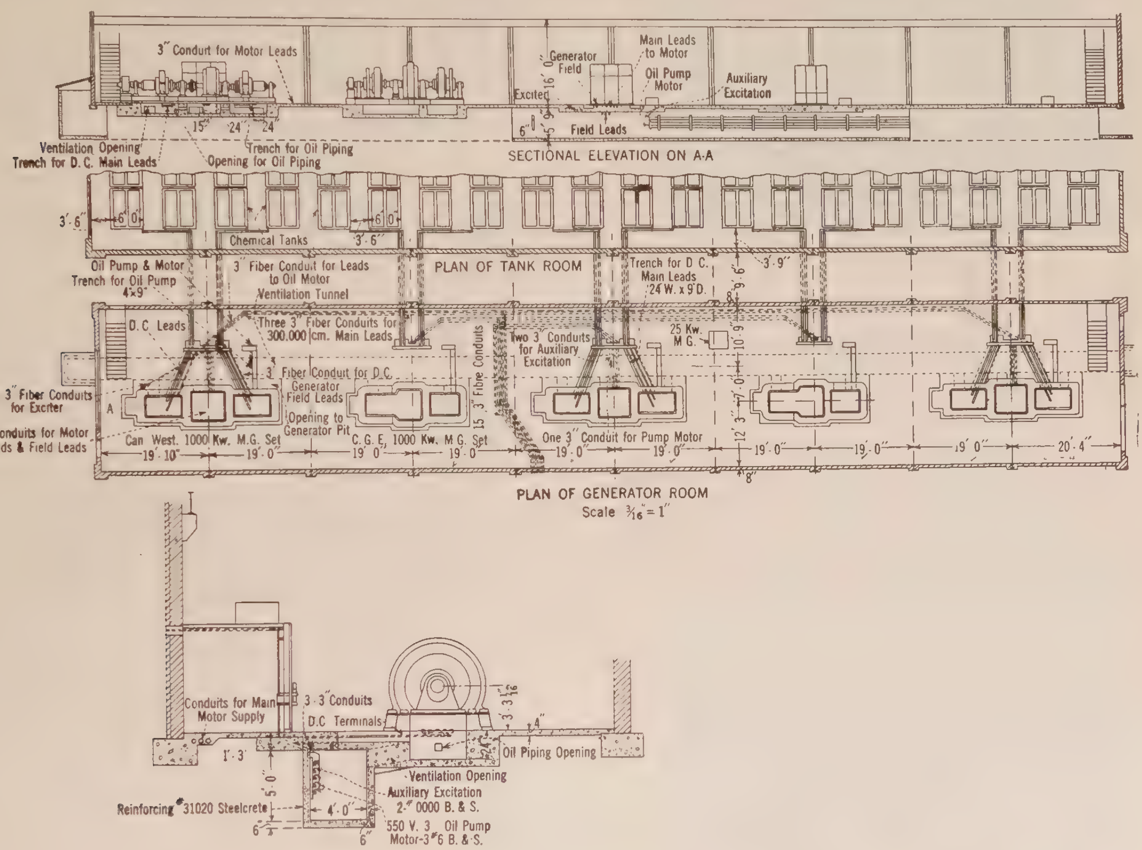
concrete. For the purpose of erecting and facilitating the making of repairs, these rooms are served with a 10-ton (9075 kg.) electric crane, having an electric travel and hoist, the traverse being manually operated. No. 1 Generator Room has seven double-ended sets while No. 2 has six each consisting of 2500-kw. 125-volts, 4000-ampere (maximum) generators. The two d-c. generators are direct-connected to a 1150-kv-a. synchronous motor, the exciter for which is connected to one end of the shaft. All the machines are arranged longitudinally with the building as can be seen from the photograph.

ventilation. Approximately 30 tons (27,400 kg.) of copper was used in connection with this installation.

Motor Generator Sets

Let us now turn our attention to the motor generator sets. The over-all length of the Westinghouse bed plate which is one single casting is 28 feet (7.62 m.) and the total weight, including the oil pump, is approximately 71,000 lbs. (32,200 kg.) or 71 pounds (32.2 kg.) per kilowatt. Holding down bolts are used, the bed plate being grouted in on top of the foundations.

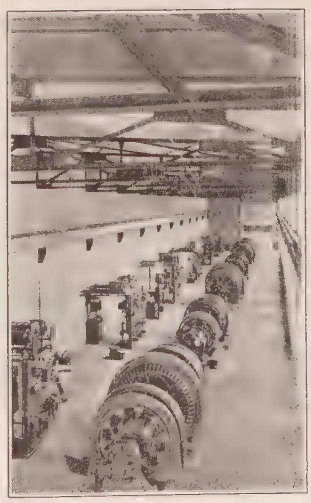
The generators are 8-pole shunt-wound interpole



The switch boards are located between the sets and the wall adjoining the tank room. This arrangement being decided upon so as to minimize the amount of copper bus used in connecting the tanks.

In the early development of the plant, considerable thought was given to the arrangement of a transfer bus in order that any set of tanks might be connected to any machine, thereby permitting more frequent inspection of the units. But when the yearly interest on a bus of the required size and the high cost of copper at that time was considered, it was decided the investment would not be justified.

The d-c. bus bars from the generators to the switchboards and from the switchboards to the tanks, are made up of four 5-16 inch (8 mm.) x 4 inch (10.1 cm.) copper bars separated by 5-16 in. (8 mm.) spacers for



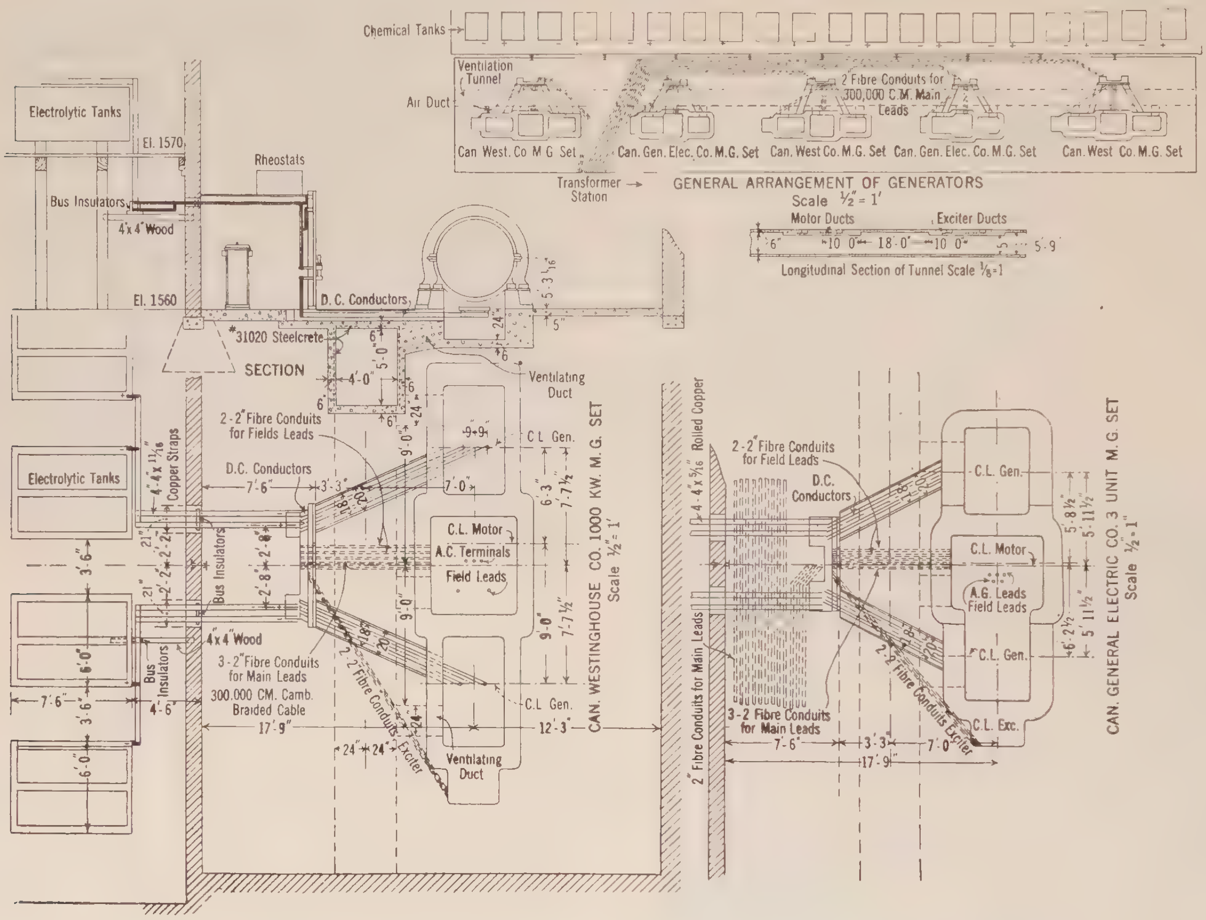
Generator Room

type of 500-kw. capacity and have a voltage regulation of from 50 to 125 volts. The speed is 600 rev. per min.

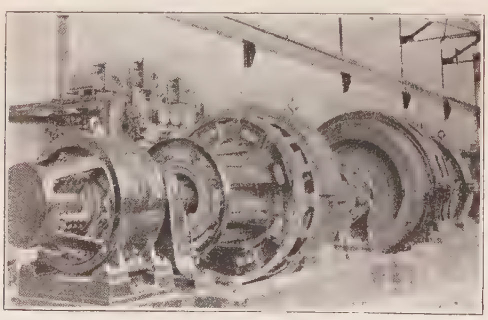
Two note worthy features are the commutator and the interpole or commutating pole winding. The length of the commutator is 2 ft. 2.5 in. (67.2 cm.). The diameter is 1 ft. 10 in. (53.3 cm.) The peripheral speed is 3970 ft. (1210 m.) per minute.

With commutators of this length and speed, it has generally been found necessary to shrink a steel ring around the center of the commutator, but in the case equipped with radiators to aid in expelling the heat generated.

"Le Carbone" soft graphite brushes are used, operating at a current density of 63.5 amperes per square inch. (12.5 amperes per sq. cm.) A spring tension of 1.25 pounds per square inch (0.15 kgm. per sq. cm.), *i. e.*, 1.75 to 2 pounds (0.79 to 0.90 7 kg.) per brush has proved to give the best satisfaction. This, of course, necessitates having the mica undercut to a depth of about 1/16 inch (1.5 mm.). The peripheral speed is



of three machines, this has been overcome by the use of three "V" rings which allows the whole face of the commutator to be utilized for the collection of current. All commutator bars, of which there are 128, are sufficiently high to prevent dirt from sticking in the recesses. The commutators revolve in a leading direction, *i. e.*, they revolve from the heel of the brushes. This has given the best possible wear on the brushes and has minimized their tendency to lock in their holders.



Canadian Westinghouse Motor-Generator Set

The interpoles are arranged so that the coils receive only one half armature current. This being attained by dividing the total number of interpoles into two sets and connected series multiple. The field frame is of high grade iron and the poles so proportioned so as to minimize the armature reaction.

The shunt field winding is separately excited. The four pillars which support the bearings are insulated from the bedplate, thus preventing the circulation of stray currents through the bearings which would have a tendency to pit both the shaft and the bearings.

The generators were subjected to an insulation test

of 1500 volts a-c. for one minute in accordance with the rules of the A. I. E. E. The insulation will stand 90 deg. cent. without injury. The generators have an efficiency of approximately 91 per cent at full load.

As can be seen, the synchronous motors are located in the center of the set, being 1475 h. p. output 1158 kv-a. input, 3-phase, 2200-volt, 60 cycles, 600 rev. per min. 314 amperes per terminal.

The stator or armature winding is a twelve pole single star connection. The stator consists of a cast iron frame. The inside of the frame being provided with ribs which have dovetails machined in them to receive the armature punchings which have dovetails to correspond. The outside of the frame is provided with large ventilating ducts to provide a good circulation of air. The armature core, which consists of built-up laminated sheet steel, is held in place by end plates, there being ventilating spaces provided at intervals across the armature.

The armature coils are machine wound and of the diamond type. These are formed and insulated before being placed in the slots, there being two in each slot held in place by fiber wedges. The ends of the coils project beyond the armature and are securely corded to a cold rolled-steel ring which is supported by cast iron arms bolted to the frame. This has been done to protect the coils against any undue magnetic strains.

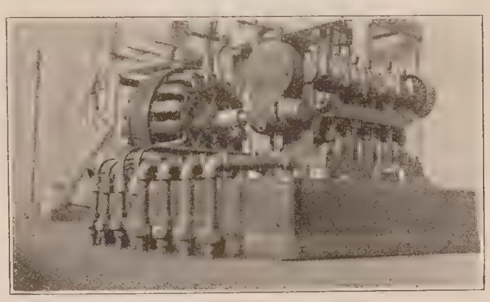
The starting winding is of the interconnected pole-face or amortisseur winding.

The rotor consists of a cast steel spider with laminated steel poles and a copper strap winding for the field. The spider has machined dovetailed slots into which the dovetail projections of the poles are fitted and are held firmly in place by tapered keys. A small end plate is bolted on each side of the pole to prevent the keys from moving sideways. These plates are made wider at the top and adjusted in a radial direction so as not only to support the field coils on the bottom side, but also to make the coils fit the poles snugly and firmly, thus eliminating any trouble due to loose field coils, especially after the motor has been in use for a long time.

The bedplate is so arranged that the armature can be slid clear of the rotating field by means of jack screws for this purpose which is of aid in making inspections and repairs.

The motor was subjected to the following insulation test as recommended by the A. I. E. E., field 1500 volts a-c. for one minute and armature 5000 volts a-c. for one minute. The operating efficiency of the motor at full load is approximately 94.5 per cent.

The exciter is a 125-volt, 200-ampere type *"S A"* 4 poles, 2 interpoles, compound-wound generator mounted on the extreme end of the shaft, in other words overhung. To minimize the starting current to approximately 400 kw. An oil jack or high-pressure duplex pump forcing a film of oil under the bearings at a pressure of 1000 lb. (458 kgm.) per sq. in. (6.4 sq. cm.) has been used. This eliminates the static friction to such an extent that the whole revolving member whose weight is approximately 9 tons (8225 kg.) can readily be turned by hand. This oil jack is on the floor at the left hand side of the switchboard. The whole pump unit is self-contained, the base of same being the oil reservoir having an approximate capacity of 10 gal. (378 liters). The pump is driven with a 1-h. p., 110-volt, 3-phase type C. C. L. induction motor connected to the pump through a worm gear. The



OILJACK

pump itself has four cylinders, each cylinder being equipped with high-pressure relief valve.

CANADIAN GENERAL ELECTRIC MOTOR GENERATOR SETS

The over-all length of the Canadian General Electric bed plate which is built up in three sections, bolted together, is 21 feet 9 inches (6.62 m.). The total weight of the set is approximately 81,000 pounds (36,700 kg.) or 81 pounds (3.6.7 kg.) per kilowatt. This bed plate employs no holding down bolts.

CANADIAN GENERAL ELECTRIC MOTOR-GENERATOR SET

The generators are 10-pole shunt wound machines of the interpole type and of 500 kw. capacity. They have a voltage variation of from 0-125 and speed of 514 rev. per min.

The interpoles received full armature current, consequently are of a massive construction. The length of the brush bearing surface on the commutators is 1 foot 7 inches (48.1 cm.) diameter 2 feet, 6 inch (76 cm.) giving a peripheral speed of 4025 feet (1228 m.) per minute. The commutator is built up of 140 bars and revolves in a leading direction.

The commutators are operated with a graphite

brush manufactured by the Morgan Crucible Company, having an operating current density of 47.6 amperes per square inch (12.2 amperes per sq. cm.). The spring tension being 1.5 pounds per square inch (0.15 kg. per sq. cm.). This of course necessitated having the mica undercut.

Note should be made of the ruggedness of the yoke supporting the brush arms; this being a characteristic feature of the machine. The field frames and brush yokes are split horizontally which is of great assistance during erection or the making of repairs. This feature is also found on the Westinghouse sets. The bearings for both makes of machines are two part and are provided with oil ring lubrication, together with sight feed oil gages.

The temperature rise after operating at full load is in the armature 40 deg. cent. in the commutator 55 deg. cent. and in the fields 40 deg. cent. The generator efficiency at full load is 92 per cent.

The motor of this set is a Type *A T I* 1150 kv-a., 2200 volts, 60 cycles and runs 514 rev. per min. Two bearings are insulated from the bed plate to prevent the circulation of shaft currents.

The stator winding is a 14-pole single-star connection. The bed plate is so arranged that the armature may be slid clear of the revolving field if necessary. The starting winding is of the inter connected pole face type, the bars being of a special high-resistance monel metal alloy.

The operating efficiency of the motor is 95 per cent at full load. The exciter which is a 126-volt, 11 kw. six-pole machine is mounted on the end of the shaft.

Artificial Loading of Generators

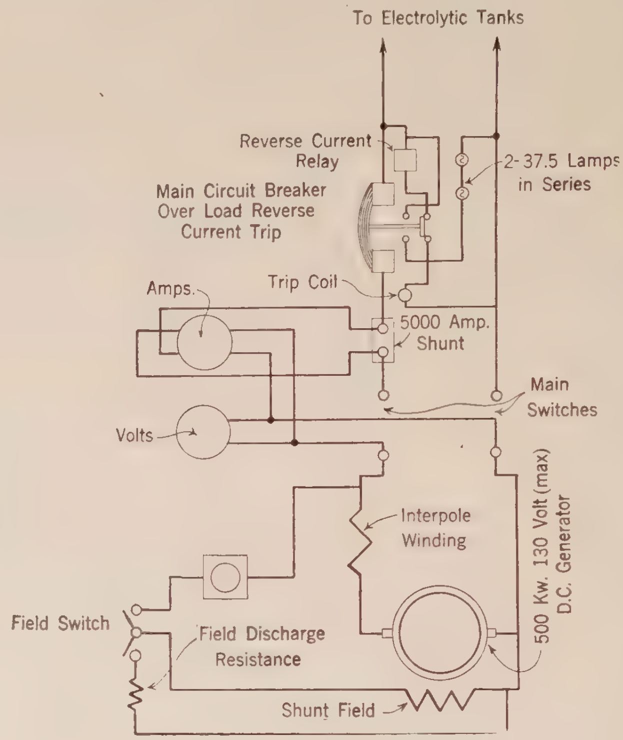
A note worthy feature during construction was the ease with which the d-c. generators were artificially loaded before going into service, this being done principally for seasoning the commutators. It was only necessary to insert jumpers connecting the bus bars of each generator in multiple and apply the loading back test, commonly known as the "Hopkinson" test. The current taken by the motor being only that required to overcome the losses of the set.

The Auxiliary Exciter

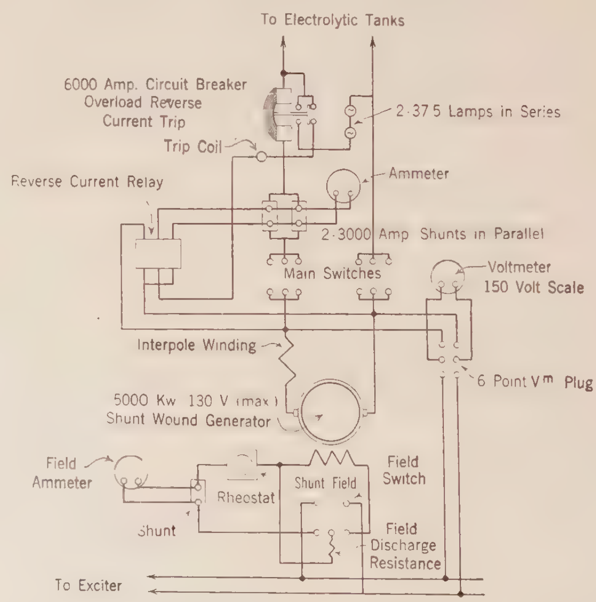
The auxiliary exciter consists of a motor generator set. The motor is of 40 h. p. and is 2200-volt type C. C. L. machine. The generator is rated at 25 kw. and 125 volts. This set not only serves as an axuiliary exciter but also as a source of supply for the cranes in the generator rooms and tank rooms as well as a source of power for a research laboratory. This set is provided with a suitable black marble switchboard on which is mounted the necessary instruments.

Ventilation

The frames of the generator sets and the neutral connections of all the instrument transformers, are securely grounded to a 250,000 cm. ground bus which runs the full length of the generator room. This bus is located in a tunnel under the floor space between the machines and the switchboard. It is 4 feet (1.22 m.) high and 4 feet (1.22 m.) wide, and serves for two purposes. One of these is that it contains the auxiliary exciter bus as well as a 3-phase, 110-volt circuit for the



Canadian General Electric Wiring Diagram



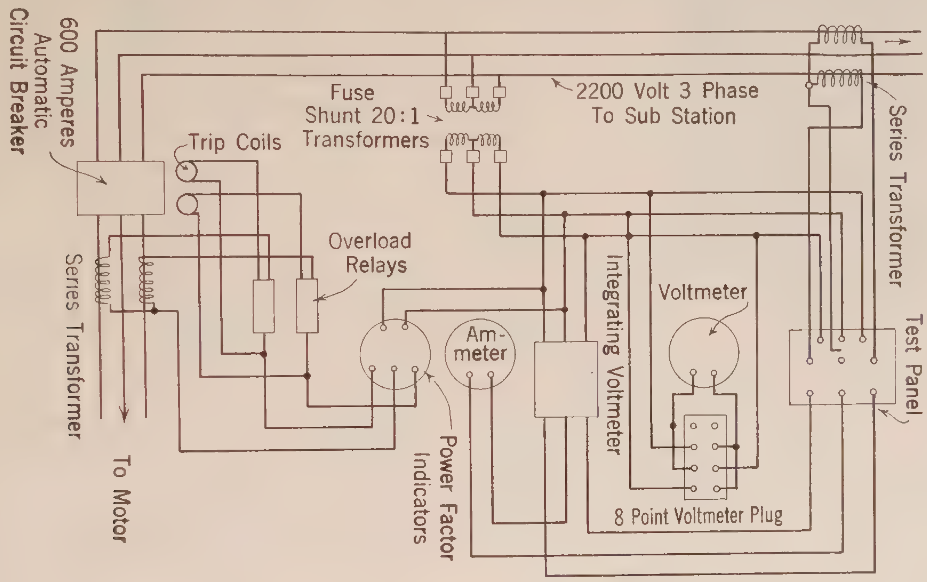
Canadian Westinhgouse Wiring Diagram

Westinghouse oil pumps, that it also contains the station lighting circuits.

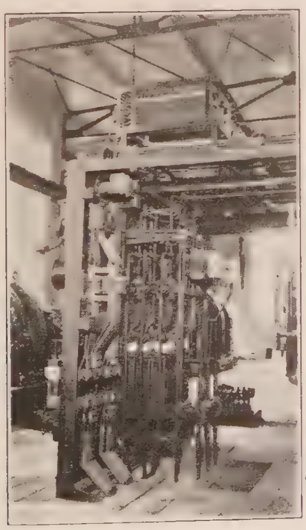
For the purpose of ventilating the machines, air is drawn in through ducts connected to the tunnel; each motor and generator having its own duct, and the warm air is exhausted through cupolas on the roof.

Switchboards

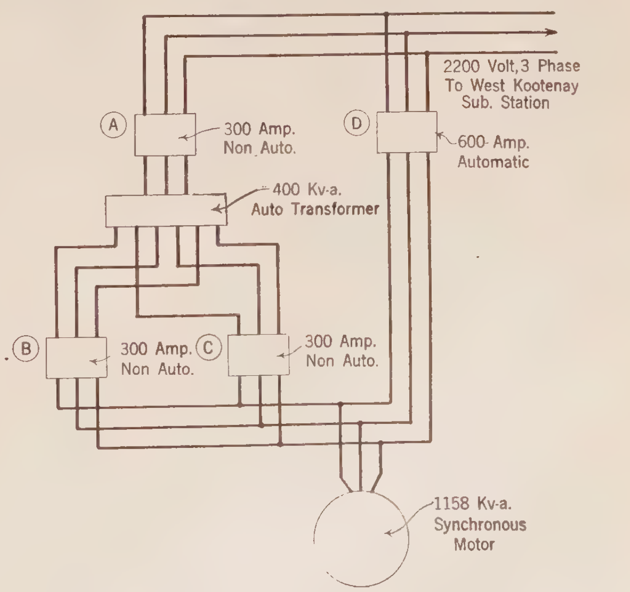
The switchboards are of the standard three-panel type on which is mounted the complete apparatus for the control of the sets. On the generator panel is mounted an ammeter which is connected in the tank circuit. These panels are equipped with a reverse current feature adjusted so that in case of power failure or the motor dropping off the line, the counter e. m. f. of the cells would not motor the set by acting as a primary battery. This counter e. m. f. is made use of as an auxiliary lighting source, each switchboard being equipped with lights, receiving current from the tanks they supply. This is accomplished through a small automatic switch mechanically connected to the d-c. breakers which in turn are controlled from the reverse current relays. The a-c. or synchronous motor panel is marked by its simplicity; in fact, simplicity is one of the outstanding features of the whole plant. On the upper portion of the panels are mounted the indicating instruments. Test blocks have been installed, thus permitting the checking and testing of instruments under load. The motor is protected by inverse time limit alternating-current overload relays. The motor panels of the two manufacturers differ in some respects. With the Westinghouse panel the switches are mounted directly behind, one a Type B-non-automatic, 2500-volt, 300-ampere and the other a type B automatic oil circuit breaker of 600 amperes at 2500 volts. Two type *B* non-automatic, 300-ampere, 2500-volt oil circuit breakers are mounted on the wall directly at the rear of the switchboard over the auto-transformers and are mechanically connected with operating handles on the front of the board by bell



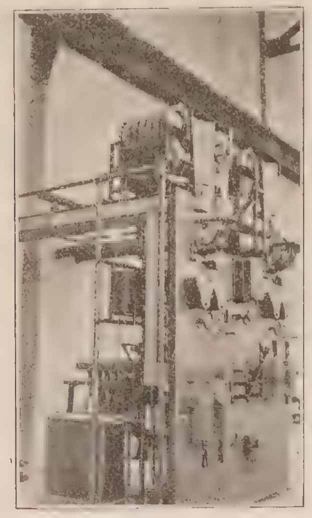
Instrument Wiring, Canadian Westinghouse Switchboard. Motor Panel



Rear Canadian Westinghouse Switchboard

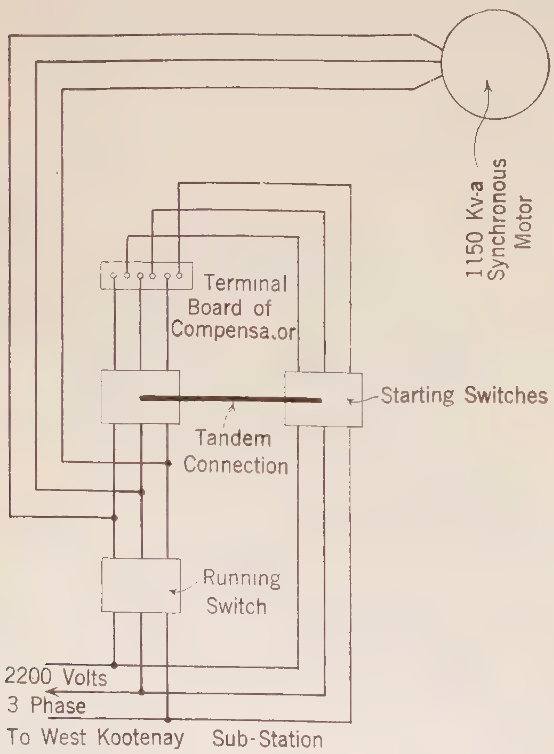


cranks and connecting rods. The 300-ampere non-automatic switch mounted directly at the rear of the panel is the magnetizing switch for the primary of the auto-transformer and is only in service during the period of starting. The next adjacent handle is the



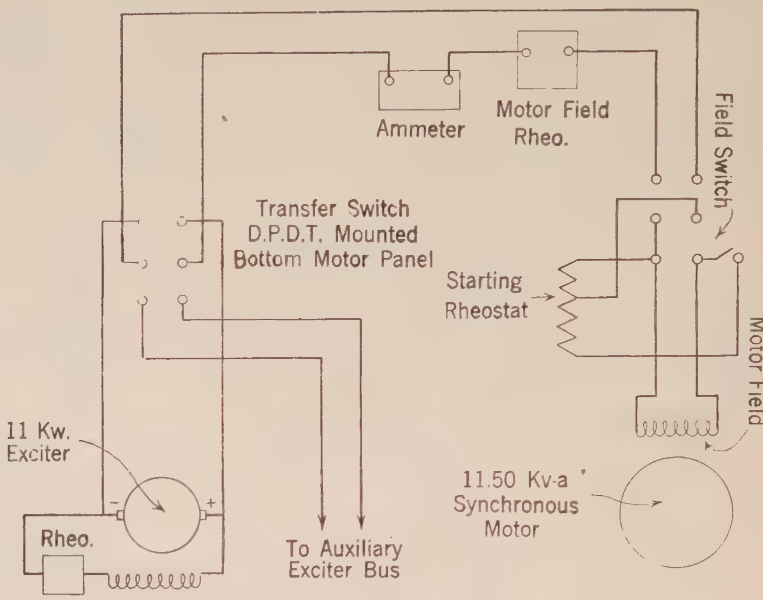
Canadian General Electric Switchboard

first or 50 per cent tap, *i. e.*, 1100 volts. The next handle is the 70 per cent tap or 1540 volts when 2200 volts is impressed on the primary. These switches are all mechanically interlocked to permit the proper sequence of operation. The auto-trans-



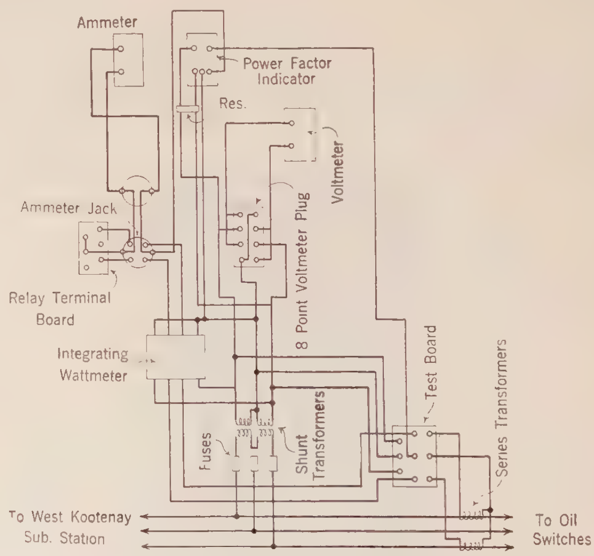
former, capacity 400 kw. is a self-contained, 3-phase oil cooled transformer with various taps having been brought out so that the following voltages may be obtained, 330, 485, 595, 770, 1100 and 1540.

The procedure of starting the sets is very simple. The motor being started as an induction motor, the rotor being equipped with an interconnected pole-face winding. After the machine has attained synchronous speed this winding acts as a damper to retard any



tendency to hunt. The revolving field is shunted through a 3.1-ohm resistance to decrease the induced voltage in the field at the start to 85 volts.

The Canadian General Electric switchboard is very similar to the Westinghouse with the exception of the



Instrument Wiring, Canadian General Electric Switchboard

motor panel. A unique feature of this board is the carbon break field switch mounted at the rear of the panel and operated from the front by means of spade handle and connecting rod. Only three oil switches are required; the magnetizing and starting switch are

mechanically connected in tandem, *i. e.*, they operate simultaneously. The method of starting is practically similar to that of the Westinghouse set. The motor being started as an induction motor during which time the rotating field is shunted through a resistance of 35 ohms. This reduces the induced voltage, which is due to the transformer action, to 850 volts at the moment of starting. On the motor reaching full speed, the revolving field is energized to full strength, *i. e.*, the field current required to maintain unity power factor at no load. When this is accomplished the motor is connected to the line. The motor attains synchronous speed in approximately sixty seconds. The switches are mechanically interlocked making the board as fool-proof as possible. The motor is protected through a double pole, overload inverse time limit relay operating a d-c. tripping coil.

Power Cables

All the power cables run from the Power Company's switches to the motor generators. They supply through 4-in. (10.1 cm.) "Orangeburgh" fiber ducts embedded in concrete under the floor. These cables are of 300,000 cm. and are insulated with varnished cambric which in turn is protected with a heavy braid impregnated with a moisture repelling compound.

Load Characteristics

The load, which is wholly a synchronous motor load, is most desirable on account of its great flexibility as a power-factor corrector. This load has been a great help to the power house, cutting down the lagging kv-a. at the generators, which is mostly caused by the rest of the load on the power company's system being inductive. The average power factor at the power house which is 32 miles (51.2 km.) away is 0.98. Excellent voltage regulation is obtained at the power company's substation bus due to this synchronous motor capacity; the voltage never varying more than 2.5 per cent of the normal voltage.

The synchronous motors can be operated as synchronous condensers so long as the armature current does not exceed 15 per cent of full load current and the temperature rise does not exceed 40 deg. cent. If the temperature rise does not come up to 40 deg. cent. 25 per cent increase in armature current is possible.

For electrolytic purposes, advocates of the rotary converter are to be found; their main point of argument being their higher efficiency. They recommend the use of single units of about 5000 kw. capacity. However smaller units in d-c. generators have many advantages over the rotary converter; one of these being the ease with which the d-c. voltage can be regulated. The rotary converter requires expensive inductive regulators or synchronous boosters on the a-c. side also expensive starting equipment when compared with that of the synchronous motor.

With the large units, they are usually operated at about 500 volts on the d-c. side, which of course, means a large number of tanks in series. In the event of a breakdown, in either the tank system or the rotary, a much larger section of the plant is affected than would have been the case had smaller direct-current generators been used. Where a large corrective effect for low power-factor is desired, the rotary converter should not be used as a synchronous condenser, nor is it possible to obtain absolutely smooth operation from a rotary at the end of a long line having a high ohmic resistance. The rotary even with all its latest improvements is still a trouble maker at times and it is a question whether the saving in power brought about by its use will offset the cost of repairs and general up-keep when compared to a direct-current generator driven by a synchronous motor.

In one large plant it has been found necessary to install motor generators of sufficient capacity to keep the zinc from redissolving back into the solution when the rotary converters are down for repairs. To circulate a current to prevent the zinc dissolving, the motor generator would have to be approximately half the capacity of the rotary-converter. This greatly increases the electrical investment with accompanying decrease in earnings per kw. of generating equipment installed.

In the plant under discussion, this protection could be brought about by installing a transfer bus, when the unit shutdown could be transferred over to another generator, thereby not interfering with the operation of the plant to any great extent but as already mentioned it was not considered that the large investment in copper bus would be warranted.

Air Compressors

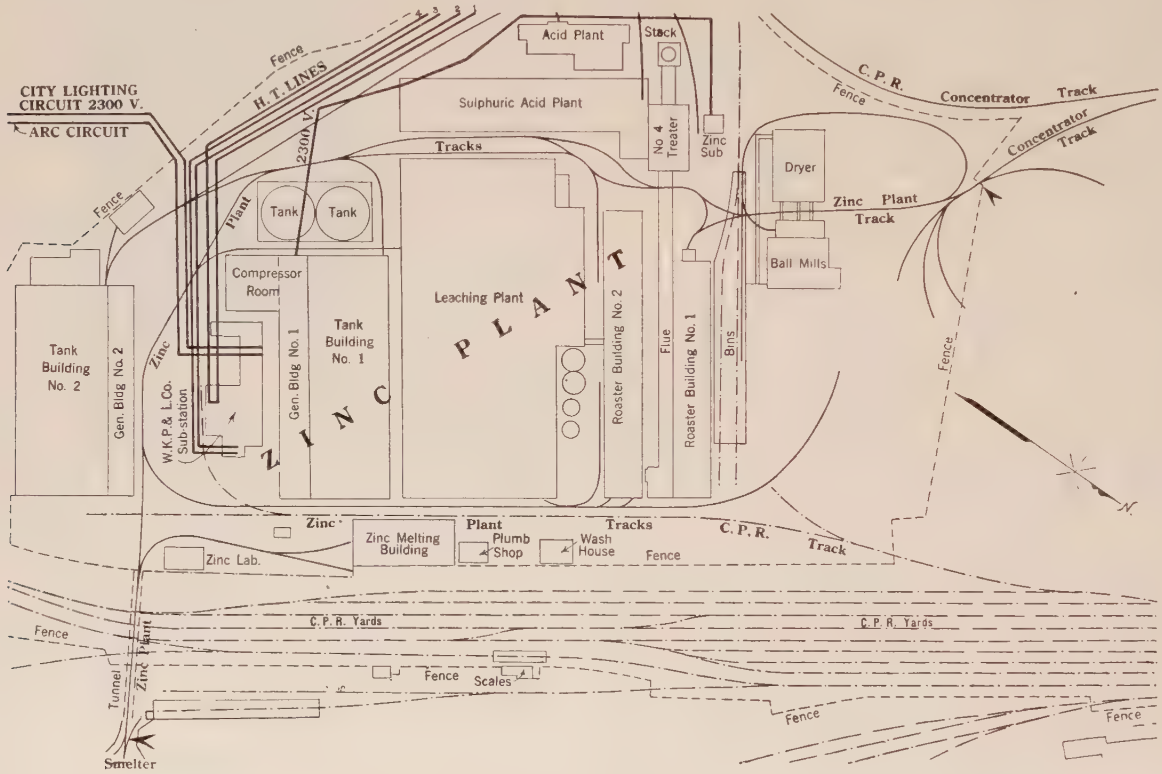
We will now turn our attention to the air compressors which are located at the far end of No. 1 generator room. This wing is of similar construction to that of the generator room. The compressors are operating at an elevation of 1558 ft. (475 m.) above sea level under an atmospheric pressure of 13.9 lb. per sq. in. (978 kg. per sq. cm.) barometer 28.3 in. (717.5 m.m.) mercury. These compressors are a very vital part of the zinc plant, as air is used wholly for agitation, and the circulating of the different acid solutions. When the plant was first put into operation, the agitating of the solutions was done mechanically and the solutions were circulated by means of pumps. These pumps soon gave a great deal of trouble on account of the very severe operating conditions.

The first compressor installed was a Rand Ingersoll, with a capacity of 1650 cu. ft. (49.7 cm.) of free air per minute at a pressure of 35 pounds (15.9 kg.) speed 125 rev. per min. and belt-driven from a 200 h. p., 2200 volt, form "*L*" (internal resistance) Canadian General Electric induction motor. As the size of the plant increased, and the demand for air became greater, it became evident that the compressor plant was inade-

quate to cope with the increased demands and therefore it became necessary to install additional units. In the end, the capacity of the first compressor was increased by the addition of an additional cylinder which doubled its capacity.

This compressor has an automatic unloader working on both cylinders; in fact, when the other units are working, this unloader regulates the whole system. This compressor is now driven with a Canadian Westinghouse 300-h. p. type "C. C. L." 2200-volt, 490 rev. per min. induction motor. The motor is controlled from a panel on which are mounted, the starting switches, instruments, relays and low-voltage release.

The second compressor is of particular interest as this machine has been practically rebuilt, being taken from one of the company's mining properties where it had been operating as a steam unit for a number of years. It is a two-cylinder unit and by various valve arrangements can be operated; compounded, two cylinders in parallel or each cylinder separately. Usually it is operated compounded with a capacity of 3200 cu. ft. (90.5 cu. m.) of free air per minute, at a gage pressure of 80 lb. (36.3 kg.). With the two cylinders in parallel, the capacity is 4800 cu. ft. (136 cu. m.) at a pressure of 35 lb. (15.9 kg.) speed 67 rev. per min. This compressor is now electrically driven; this being made possible by installing a herringbone gear on the crank shaft next to the fly wheel. The gear is driven from a pinion shaft connected to the motor through a flexible steel link coupling. The pinion shaft and pinion are in one piece having been machined from a solid steel forging. This unit is driven by a Canadian Westinghouse 600 h. p., 400 rev. per min., 60-cycle, 2200-volt, 144 amperes per terminal, squirrel-cage induction motor. The motor is controlled by a switchboard panel and a 1000 kw. auto-transformer with taps brought out by which the following voltages may be obtained: 650, 935, 1150, 1400, 1700 and 1900. That is when 2200 volts is applied to the primary. The motor is started on the 1400-volt tap taking 200 per cent full-load current and requiring from 50 to 70 seconds to attain full speed.



General Plan. Zinc Plant

No. 3 compressor has a capacity of 2000 cu. ft. (56.5 cu. m.) of free air per minute, speed 150 strokes per minute. This compressor only operates on the high-pressure system at an average pressure of 80 pounds per sq. in. (5.62 kg. per sq. cm.). Like No. 2 compressor, this machine came from one of the company's mining properties; the only change being found necessary was in the remodeling of the valve gear.

A 400-h. p. 2200-volt, wound-rotor Allis-Chalmers induction motor supplies the motive power. The motor is controlled from a suitable grey marble switchboard on which is mounted an oil circuit breaker and a six point Cutler Hammer drum controller, cutting out the different steps of resistance. On attaining full speed, the slip rings of the rotor are short-circuited. The motor has a full speed of 300 rev. per min. The starter being equipped with a "no-voltage" feature.

This compressor is rope-driven, the idlers and the tightning devices being fastened to the roof structure.

The three compressors are on one power feeder from the power company's bus. Each compressor has disconnecting switches connected ahead of the oil switches in order that the switches and starting equipment can be readily inspected.

Industrial Motors

In the rest of the plant there are practically only 550 volts induction motors varying from 5 to 200 h. p.

The 550-volt service is derived from a local substation which is within close proximity of the points of supply. The maximum capacity of this station is 1200 kv-a., there being 400 kv-a. water-cooled, single-phase transformers connected delta-delta. The primary voltage being 2200 and secondary 605. The primary has also a 1990 volt tap. Power is fed to this station over a 500,000 cm. line consisting of two circuits of 250,000 cm. This line is protected with a set of Canadian General Electric aluminum lightning arresters at each end. A three-panel switchboard controls the outgoing feeder circuits supplying, namely, a 1000-ampere circuit to the ball mills, a 600-ampere circuit to the roaster building and a 600-ampere circuit to the leaching plant. Practically all apparatus are individually driven, thereby the operation as a whole is not materially affected by the shutting down of any one machine.

The same reasons that hold for the preference of a-c. to d-c. motors in general industrial work make the a-c. motor more desirable for the zinc plant operation. There being two reasons for this: First, the relatively higher alternating voltage that can be used, *i. e.*, 500 or even 2200 volts in dry places, and second, the greater mechanical simplicity of the a-c. motors, particularly that of the squirrel-cage type which is very rugged and its initial cost, together with maintenance, being low. The operating conditions that exist in a cement mill are practically duplicated in the plant which is being described (see "Motors on Cement Industry" by R. B. Williamson, Trans. A. I. E. E., Vol. XXXVLL, 1918, page 1241.)

On account of the heavy accumulation of dust in the motor windings which interfere with the ventilation, the machines have to be frequently blown out and cleaned off. It is the writer's opinion that in such places where the dust accumulations are heavy, at times plugging the air gaps, a motor designed with a wide air gap would be more suitable. Of course, a motor having this characteristic has a poor power factor, but this could be improved if the correction warranted the investment by connecting a synchronous or static condenser to the feeders supplying the induction motors.

This plant is especially well adapted to take care of power factor correction on account of the large capacity installed in synchronous motors.

Probably the most desirable motor for this class of work would be that of the enclosed type, which would permit a very close air gap and consequently high power factor. Motors of this type are extensively used in the anthracite coal fields of Pennsylvania.

The argument generally advanced against the enclosed motor is that of the high initial cost, on account of the designer having to be more liberal with iron and copper. If, however, the enclosed motor were equipped with ball bearings, it seems only reasonable that the extra cost would be more than offset by the saving brought about in maintenance.

The roasters are arranged in two parallel lines, seven in one and six in the other. The roasters are of the wedge type; having seven hearths, each hearth having four sets of rabbles operated from the bottom by means of a bevel gear driven from a Westinghouse back geared motor. Coal is used as fuel and the roasters are fired by hand.

The gases issuing from the thirteen roasters feed into a general flue which in turn passes through the Cottrell plant (No. 4 treater). The elementary principles of the Cottrell system of dust precipitation are now generally known so that an extended theoretical discussion would be superfluous. The treater operates upon unipulsating direct current which is supplied from the rectifier room at a potential of 60 kv. The power comsumption is 28.5 kw.

The electrical equipment consists of an Allis-Chalmers 38.5 h. p., 3-phase, 550-volt induction motor, a 28-kw. 220-volt, single-phase generator and a high-tension rectifier; all direct-connected so as to operate in synchronism, and an Allis-Chalmers single-phase, 220-volt to 150 kv. secondary connected to operate at 75 kv. Low-reactance transformer capacity 25 kv-a. The transformer is of special design and is constructed in such a manner as to be amply protected against all excessive strains placed upon the insulation due to the electrical surges arising at times from momentary short circuits, or arcing in the treater, as arise continuously from the use of the mechanical rectifier, which makes and breaks contact in the high-tension circuit.

The voltage in the treater is controlled from the switchboard through resistance control by means of which the field excitation in the generator can be varied over a wide range. This controls the generator potential which in turn varies the voltage impressed upon the treater. The voltage in the treater can also be regulated by shifting the position of the stationary contacts of the rectifier relative to the poles of the generator by which the proportion of the current wave can be controlled. This method of regulation, however, is only used for the making of general ajdustments and is not resorted to in the course of ordinary operation.

The rectifiers are usually set once and for all in such a manner as to give contact to that part of the wave which will assure smoothest operation when the treater is operating under normal conditions. But when the conductivity of the gases varies radically, it becomes

desirable at times to change the position of the rectifier contacts.

The electrical equipment in connection with the concentrator consists of:

No. of Motors	H. P.	Type	Make	Speed	Motor Driving
1	15	K. S.	C. G. E.	1200	Bucket Elevators
1	25	K.	"	"	Filters
1	15	K.	"	"	Thickeners
1	5	K. S.	"	"	Ball Mill Classifier
1	15	K. S.	"	"	Conveyor to Ball Mill
1	7.5	C-C.L.-B.G.	C. W.	1120	Bins
1	5	K.	C. G. E.	1200	Oliver Filter
1	50	K.	"	"	Pump
1 x	200	L.	"	600	Flotation Machines
1 x	100	K. S.	"	720	Ball Mill

The above motors are 550-volt machines with the exception of those marked "*X*" which are 2200-volt.

The equipment also included two Ding magnetic separators, speed 440, operating on 110 volts d-c. The 550-volt service is obtained from two 30-kv-a., 2200-550 volts (pole type) Canadian General Electric transformers connected in open delta. At the time of writing, a mineral separator consisting of a battery of flotation machines was being installed in direct connection with the leaching plant. This installation will require approximately 200 h. p. in 550-volt induction motors.

The motor equipment in the different departments consists of:

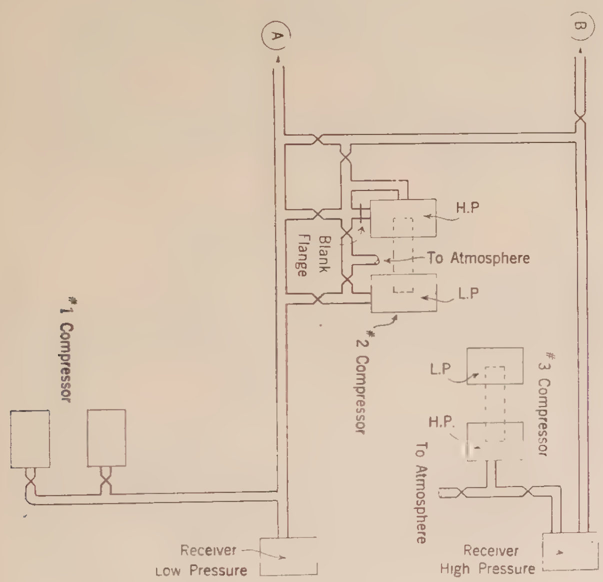
	No. of Motors	H. P.	Type	Make	Speed	Motor Driving
Ball Mills	3	175	K. 1	C. GE.	600	3 Tube Mills 5 ft. x 18 ft. (1.52 M. x 5.48 M)
	1	5	C.C.L.—B.G.	C. W.	1120	Belt Conveyor
Roaster Building	1	10	C.C.L.—B.G.	C. W.	1120	7 Hearth Wedge Roasters
	2	7—5	" "	"	"	" " " "
	10	5	" "	"	"	" " " "
	7	7—5	" "	"	"	Belt Conveyors
	1	7—5	" "	"	"	" "
	1	5	" "	"	690	" "
	1	5	" "	"	1120	" "
	1	10	K. 1.—B. G.	C. G. E.	1200	Spiral "
	2	7—5	C.C.L.—B.G.	C. W.	1120	Spiral "
	4	5	" "	"	"	" "
	1	5	I.L.T.—B.G.	"	"	"
	7	7—5	C. C. L.	"	"	Fans
	2	5	"	"	"	"
Dryers	2	10	C.C.L.—B.G	C. W.	1120	2 Dryers 5 ft. x 40 ft. (1.52 M. x 12.17 M.)
	1	7—5	K2 C	C. G. E.	1200	Belt Conveyor
Cottrell Plant	1	38—5	AllisChalmers		1750	Single Phase Generator 110—250 V. 113— 5 A.
Leaching Plant	2	30		Fairbanks Morse	900	2 Gear Driven Triplex Gould Pump
	2	20	K. S.	C. G. E.	1200	Storage Pumps
	1	15	C. C. L.	C. W.	1120	Pumping electrolyte from filters to tank room
	1	10	K.	C. G. E.	1200	Pump, Thickeners to Pachucas
	1	20		Allis Chalmers Bullock	830	" Pachucas to Thickeners
	1	20	K.	C. G. E.	900	" " " "
	1	30	C. C. L.	C. W.	650	2 Pumps, from thickeners to top of building
	1	5	K. S.	C. G. E.	1200	Pump, from filter to thickeners
	6	5	C. C. L.	C.W.—B.G.	1120	Dorr Thickeners
	1	5	C. C. L.	C.	690	Dorr Thickeners
	1	5	C. C. L.	C. W.	1120	Drag Classifier
	1	5	"	"	690	" "
	1	7—5	" —B.G.	"	1120	" "
	3	7—5	" "	"	"	Dorr Thickeners
	1	3	"	"	"	Filter
	1	5	K. T.	C. G. E.	1800	Pump
	2	5	C. C. L.	C. W.	1120	Spiral Conveyor
	1	5	" —B.G.	"	"	Belt Conveyor
	1	5	"	"	690	Bucket Elevator
	1	5	K. T.	C. G. E.	1200	" "
	1	10	C. C. L.	C. W.	1120	" "
	1	10	"	"	690	Machine Shop
Zinc Melting Room	1	7—5	C. C. L.	C. W.	1120	Drossing Machine
	2	5	"	"	1120	Pipe Threading Machines
Lead Burners	1	5	K. T.	C. G. E.	1800	Emery Wheel
Plumbing Shops	1	3	C. C. L.	C. W.	1120	Drill Press

C. W.—Canadian Westinghouse Company, Ltd.
C. G. E.—Canadian General Electric Company.
B. G.—Back Geared.

Summary of total equipment installed in the Zinc Plant:

Name of Departments	No. of Motors	Total H. P. Installed	Aver. H. P. per Motor Installed	Aver. Power Consumption	Aver. Load Factor
No. 1 Generator Room	11	10626—5	966—4	6200 kw.	78
No. 2 Generator	9	9046—5	1005—1	5000 kw.	74.25
Room, compressors, incl. Vacuum pump	5	1375	265	690 kw.	67.3
Ball Mill	4	530	132—1	243 kw.	61.5
Wedge Roasters, Dryers and Cottrell Plant	44	323—5	7.32	88.6 kw.	35.8
Leaching Plant, Zinc Melting Room	37	353	9.95	113 kw.	43
Lead Burners and Plumbing Shops Concentrator	10	4375	43.75	275 kw.	84.5
Total	120	22692	186	12609.6 kw.	74.25

The total horse power in motors installed per ton (916 kg.). Zinc is 215.8 h. p., this being figured from the theoretical daily capacity at 100 per cent efficiency, of the plant which would be 105.6 tons. (95,800 kg.). The theoretical capacity is computed from the total ampere-hour capacity for 24 hours of the generator equipment: this being 2,496,000 ampere-hours. Horse power installed per ton figuring on the actual output of 85 tons (77,100 kg.) would be 266.9.



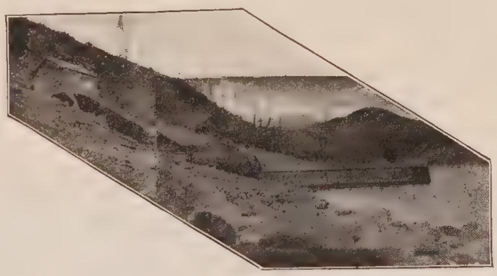
Air Compressor Layout

Cottrell Plant

Water Supply

A very interesting development of vital importance to the continuous and successful operation of the reduction plant is the water supply system, this being of the most modern nature. After having experienced practically a total shut down one very severe winter due to a water shortage, plans were immediately made for the construction of a modern pumping station by which the plant as a whole would always be assured of an ample supply of water. In such a plant as is under discussion, there are very few departments that do not use water.

The pumping station is located about a mile (1.61 km.) up the Columbia River from the reduction plant; this point having been chosen on account of the water there being pure and free from sediment or taint which would make it unfit for domestic or other purposes. Also it is not affected by the drainage or seepage from the plant. The flat or bench on which the plant is situated is about 250 ft. (76 m.) higher than the average water surface in the river. The greatest obstacle to be overcome was the great rise and fall of the water in the river due to the change of seasons and which at this point amounts to about 50 ft. (15.75 m.). The company's engineers overcame all these difficulties and have constructed a pumping station of large size and great strength at a point low enough to draw up the water when the river is at its lowest stage. With a sloping tunnel entrance running from a point up the river bank well above the highest known water mark, the whole has been covered and made absolutely water tight. This tunnel is 82 ft. (25 m.) in length. The pumps are housed in an arched concrete house of extremely heavy construction, being designed so that the total weight of the building and machinery overcomes the tendency of the structure to float at high water and at the same time to safely withstand the great pressure of water when the river is in flood. At



Pumping Station at Low-Water Period

this time there is 30 (9.15 m.) or 40 feet (12.2 m.) of water over the roof of the pump house.

The floor of the pump house is 1350 feet (412 m.) above sea level. The building is 30 feet (9.15 m.) long and 20 feet (6.1 m.) wide with an arched roof 14 feet (4.27 m.) in height and 18 in. (35.8 cm.) in thickness. Through the bottom of the pump house three 10-inch (25.6 cm.) steel pipes lead downward to a covered suction forebay from which the supply is drawn. The

Pumping Unit

pumping equipment consists of three 4-stage turbo pumps manufactured by Goldie and McCulloch, Galt, Ontario. These pumps have a capacity of 1500 gal. (5675 liters) per minute against a maximum lead of 337 feet (102.6 m.) Each pump has a 10-inch (25.6 cm.) delivery connected to the 16 inch (40.7 cm.) main which runs up through the tunnel and is connected to the old system.

The pipe lines are built for two pumps, to be operating continuously, the third to act as an auxiliary.

Starting Equipment for Pump Motors

Under such conditions the plant has a capacity of over 4,000,000 gal. (15,130,000 liters) every 24 hours, or approximately a sufficient supply for a city of 30,000 people.

The pumps are direct-connected to Canadian Westinghouse type *"H S"* induction motors operating at 1150 rev. per min. These motors are rated at 200 h. p. but will deliver 250 h. p. continuously with a rise in temperature of 55 deg. cent. They are started through auto-transformers which are mounted on the floor directly under an oil circuit breaker. The breakers are for motor protection and are equipped with overload tripping coils. An ammeter has been mounted on the lid of each switch. For taking care of all seepage and leakage a 3-inch (7.6 cm.) vertical sump pump is provided; having a capacity of 180 gal. (681 liters) per minute against a maximum lead of 50 ft. (15.25 m.). The pump is driven by a 5-h. p. 550-volt type C. C. L. Westinghouse induction motor and has a speed of 1750 rev. per min. The motor is controlled by an automatic float switch.

For priming purposes when the river is below the level of the pumps, two vacuum pumps are provided, being located on the landing at the entrance of the tunnel. These are shut down from the pump room by push buttons connected to solenoids in connection with the starting switches.

Power is derived from a bank of stepdown transformers, immediately outside the building consisting of three 125 kv-a. single-phase transformers connected delta. This bank is fed from a 2200-volt line running from the power company's substation, a distance of about a mile (1.61 km.). An outdoor type oxide film lightning arrester has been installed to further insure the station against a shut down.

CORRESPONDENCE

TECHNICAL LITERATURE

To the Editor:—

The point raised by Mr. K. L. Hansen in his letter published in the April Journal regarding the large volume of technical literature is, in my opinion, very well taken.

I have been interested in the discussion on this matter which has been taking place lately and I have watched with some misgivings the gradual popularizing of the Journal which has been going on for years. There has been the tendency to cut out mathematics and to publish more descriptive material, matter of more or less momentary appeal but which, accompanied by photographs, attracts the eye.

It is not the Journal alone which has been following this course but the technical magazines generally. The motive is undoubtedly to acquire a large circle of readers with the ensuing reduction of overhead which is very attractive. But we can pay too dearly for growth. The fundamental issue as I see it may be stated thus: is the present enlarged and rather voluminous Journal doing more to advance the science than was the older and less bulky Proceedings? The real desideratum is not a wider circle of readers but a more intelligent one which will use what it reads.

Believing that this question is one of prime importance I am taking the liberty of writing to the Journal and thus further overburdening an already embarrassed magazine in the hopes of stimulating discussion and bringing out wider comment.

Philip C. Jones.

Underground Alternating-Current Network
Distribution for Central Station Systems

BY A. H. KEHOE
Associate, A. I. E. E.
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Review of the Subject.—*1. Certain experimental arrangements for an underground alternating current distribution system are covered in the paper.*

2. Low costs and characteristics satisfactory for general utilization of alternating current are contrasted with difficulty of obtaining reliability. The advantage of adopting system characteristics which will make each service suitable for lighting, appliances, and motors is indicated. There is described experience with a combined light and power network on one set of mains. Effect of voltage variation on incandescent lamp illumination is discussed. An appendix covers tests on this subject.

3. Reliability in service of standard distribution materials is considered. Tests on cables are described which indicate that for underground distribution conditions, low-voltage cables will eliminate arcing faults while high-voltage cable will not do so. An appendix of arcing tests is attached.

4. Certain factors are discussed relative to size of mains and location of transformers necessary to make the low voltage network clear its own faults.

5. There is a description of an experimental system consisting of several radial high-voltage feeders, the distribution transformers of all these being connected on the low-voltage side to a common low-voltage cable network.

6. The reactance of the transformer circuits is almost three times that of standard distribution transformers.

7. The only protective devices used are automatic circuit breakers installed in the low-voltage cables between the distribution transformers and the network. The switches open on a reversal of energy from the network and close when the transformers are in a condition to supply power to the network. The devices are sensitive enough to open on transformer magnetization energy.

8. Great reliability is obtained for the network as a switch failure on a high-voltage fault is the equivalent of a short-circuit on the secondary network.

9. Ability to switch automatically all transformers by controlling the supply end of the feeder to which they are connected allows a higher all-day efficiency due to the saving of iron loss at periods of light load. This feature also makes it easy to work on high-voltage equipment.

10. A description of the equipment used in this experimental installation and operating results of switch equipment from date of installation in April 1922 to March 1924 are given.

11. It is believed that with low-voltage a-c. underground networks arranged as described, the reliability is the same as the reliability of the sources supplying the various radial high-voltage feeders. The possibility in the future of a protected network arrangement of the supply system is mentioned.

It is the purpose of this paper to describe the design and operating results of certain experimental distribution arrangements[1] on the 60-cycle system of the United Electric Light and Power Company in Manhattan.

Alternating current distribution has had general use on overhead service because of its economy in first cost and low operating expense, and the underground service has increased rapidly in the past few years because of the above conditions. In general, this system's characteristics for utilization of the service has been satisfactory. The disadvantage found in variable speed motor applications are compensated for to a large extent, by the extremely simple constant speed motors. Other characteristics in most instances have been good.

Reliability of supply and the adoption of system characteristics for services which will make it possible to apply universally lamps, appliances and motors at any service, are the principal subjects considered in this paper.

The practise in this country has been for most central stations to supply general power service at twice the voltage used for lighting or general appliances. In a-c. distribution this resulted in having separate power services for polyphase motors. There are many advantages in having any service capable of supplying all kinds of service. The common problem, in considering the possibility of combining light and power on one set of mains and services, is the permissible variation in illumination of incandescent lamps, due to changes in voltage. The principal cause of voltage variation is the starting current required by motors. The writer was unable to discover in 1921 any published information concerning variation in voltage which was possible without having a visible change in illumination for standard incandescent lamps. Results of tests, made shortly after (described in Appendix A), indicate that two per cent instantaneous variation in voltage cannot be detected and that three per cent is the maximum possible for the highest grade service. Changes of five per cent, however, will not be observed in most conditions found in practise.

A light and power polyphase network on a single set of mains was placed in service with 300-kw. installed transformer capacity feeding from five locations and having 15 elevator motors, as well as a typical city load of apartment lighting, appliances and miscellaneous motors. The calculated maximum lighting voltage variation at the services was three per cent. Experience of 12 months' operation is that such a system will give illumination without flicker at a lower cost and

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1. In an endeavor to describe briefly the designs adopted, common terms to explain new conditions have been used. Some of these have broader meanings than are applied herein. It is believed however that the subject matter will not be misleading if these limits are realized.

that its services will be of the so-called universal type, in that lamps, appliances, or motors can be connected to any of them.

Reliability of supply is of paramount importance to any successful system. It is also desirable in designing a distribution system to use as much standard equipment as possible. Our studies of service reliability contemplated distribution from substations or other sources, with available voltages in excess of 2000 volts, and stepping down to values which were suitable for standard lamps, appliances, and motors.

Service equipment has been developed to a high state of reliability. Edison systems (d-c. network distribution) had a large share in bringing this about. Present apparatus is considered suitable for a highly reliable system.

The other elements entering into an underground a-c. distribution system are—

(a) Cables—(1) for low-voltage and (2) for high-voltage.

(b) Distribution transformers

(c) Protective devices

For reliability in operation standard cables were examined to determine their performance in case of fault. Tests were made (described in Appendix B) which indicate that if an arcing fault develops between copper and sheath, on a 60-cycle single-conductor cable of less than 220 volts, the fault will burn itself off. If an arc develops on a similar high-voltage cable, the fault will continue if the restoring voltage on rupturing the arc is in excess of 1000 volts between conductor and sheath, providing the fault current is at least 500 amperes. At 2000 volts, fault currents as low as 100 amperes will continue to arc. It is thus possible to use a network or grid of low-voltage cables which will rid itself of arcing faults. High-voltage cables, however, must be equipped with protective devices to eliminate faults on them.

If a low-voltage network is designed so that any of the conductors which become short-circuited with a low resistance path will receive enough current from the network to heat the copper of the faulty section causing an arcing fault to be set up, then the network will be able to protect itself against any faults which occur on it. With standard cables, it is necessary to have a minimum voltage gradient in the cable of at least a six volt drop per 100 ft. to melt solder in the joints or damage the insulation, and about four times this amount to melt the copper. These relations set a maximum size of network cable for any given capacity and make it necessary to have certain limiting relations for size and spacing of transformers. (Appendix C deals with solid short circuits on a low-voltage network).

With a low-voltage network which will eliminate its own faults and with high-voltage cables requiring protective equipment to handle faults which may develop, it is possible to feed from the high-voltage sources to the low-voltage network—(a) radially with a single-feeder, (b) from several radial feeders supplied from one or more synchronized sources, or (c) from a high-voltage network which in turn is fed from several feeders from one or more synchronized sources. Obviously, a reliable supply cannot be obtained for a network from a single-radial feeder. As a high-voltage network requires a quantity of expensive protective equipment and extra cable is required to obtain the slight advantage of having somewhat smaller capacity in distribution transformers, the proper arrangement appears to be a network fed in multiple from the secondaries of distribution transformers, a number of each being connected to any one of several radial high-voltage feeders.

With the use of a low-voltage a-c. network, fed from several radial feeders, the distribution of loads between different transformers made it appear desirable to increase the reactance of the standard transformers in order to more nearly balance the loads on transformers, and provide relatively high reactance paths in case a network is fed from two or more separate synchronized sources. Reactance of from two to three times the values now in use on distribution transformers is not considered excessive for such service.

Distribution transformers and, as set up previously, high-voltage cables are liable to develop faults which will persist. In providing protective equipment for the above, it was considered that by installing a circuit breaker in the low-voltage cables between each distribution transformer and the secondary network which which would open on a reversal of energy, any high-voltage fault would be disconnected from the network. The reliability of the system would be much greater than the reliability of any switch, as a failure of one device would never result in more than a shortcircuit on the secondary cables, which can be burned off without interruption to the network. In practise this is accomplished by having high-capacity low-voltage fuses on the network side of the switch, which melt in case of switch failure before the cables feeding to the network are damaged. No other protective devices are used except the customary circuit breakers on the supply end of the various high-voltage cables feeding the network.

Since it is possible to get reverse energy from the network in the form of iron loss to distribution transformers in case the high-voltage supply to any feeder is disconnected, the switches were made sensitive enough to function on these values of reverse energy and were made so that they would close automatically in case the high-voltage feeder was made alive, and circuit conditions were such that the transformers would supply energy to the network after the switches close. With this arrangement it is customary to disconnect high-voltage feeders at the supply end and the switches at each of the distribution transformers on this feeder will open automatically. By doing this at light load periods, the remaining feeders connected to the net-

work are loaded up to their maximum efficiency point, or in other words, most of the usual iron loss of the distribution transformers and regulators now out of service is saved. This also facilitates maintenance work on the high-voltage cables and transformers. It is estimated that the improvement in all-day efficiency on most systems receiving power from steam generating stations will offset a large part of the cost of the protective equipment. The elimination of all the usual protective equipment installed at distribution transformers or at sectionalizing points on the high-voltage cable is also a distinct saving.

The first installation of equipment in Manhattan was made with 29 switches supplied from four high-voltage feeders. Standard distribution transformers were equipped with external reactance, making the total reactance 8.7 per cent on this installation. (It is proposed to use 10 per cent total reactance on additions). The system was started on April 12, 1922 and has been in continuous service up to April 1st of this year.

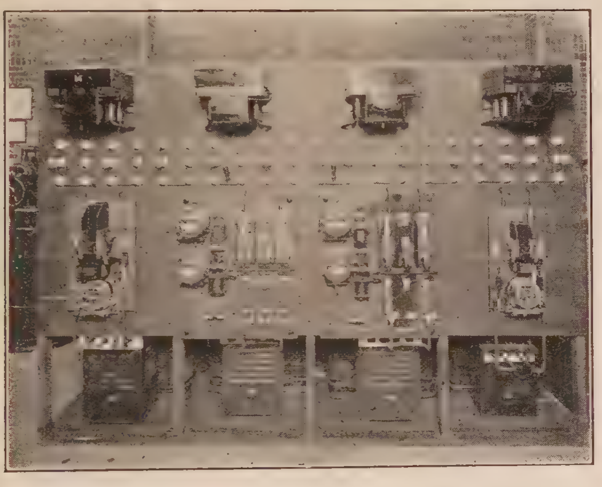

Fig. 1

The automatic switch equipment used consists of a carbon circuit breaker provided with a closing coil, and a latch which is tripped by the armature of a low voltage auxiliary relay. The circuit of the auxiliary relay is controlled by the main or master relay and as its electrical source is from the transformer secondary side of the switch, it is also used to actuate the contacts which make and break the closing coil circuit. The closing coil is thus prevented from receiving energy unless the potential is sufficient to cause the switch to close. The main relay is of the induction disc type and has two current circuits and one potential circuit, so that with the switch open one circuit is shunted across the open contacts of the switch in series with a resistance of the ballast type (tungsten lamps are generally used). The potential coil of the relay is connected across the network and the relay thus closes its contacts only if the transformer is capable of supplying energy to the network. When the switch is closed, this coil is short-circuited by the switch and the second current coil actuates the relay. This is connected to the terminals of a magnetic shunt in the circuit between the distribution transformer and the switch. It receives a large component of the current from the transformer to the network for currents of 5 per cent of switch rating. For larger current values, the magnetic shunt saturates and only allows a slight

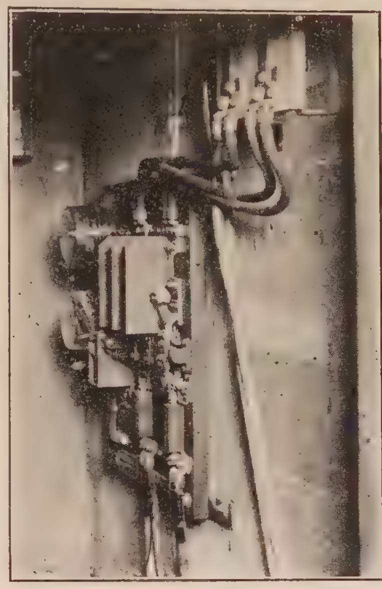

Fig. 2

increase of current in the main relay coil. This coil with the potential coil across the network makes the relay function as an energy directional device and its contacts open the low-voltage auxiliary relay circuit in case of a reversal of energy, even of the magnitude of magnetization energy of the transformer. The relay

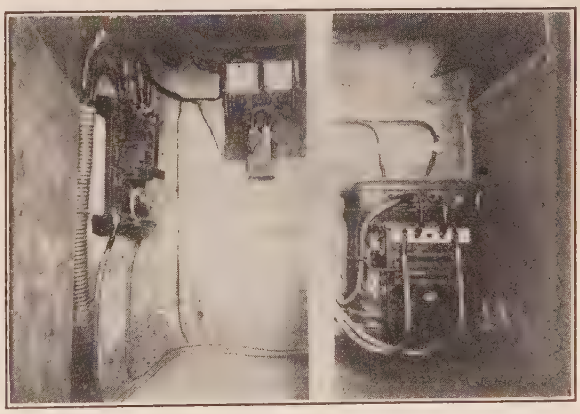

Fig. 3

has spring adjustment to keep closed its contacts with the network dead, and auxiliary electrical circuits to compensate for the spring adjustment when the network is alive and give a positive range in adjustment for either opening or closing the switch.

An auxiliary contact is provided to close a circuit to a resistance across the transformer side of the switch

when the main switch contacts are open. This resistance is used to melt a wax indicator in case the transformer secondary is made alive for several minutes without having the switch close its contacts. A failure of a network switch to automatically close is thus indicated on inspection.

Fig. 1 shows four switches connected for a single-phase demonstration. The end switches on either side are of the first type produced, while the two center switches are of the later three-pole type for three-phase

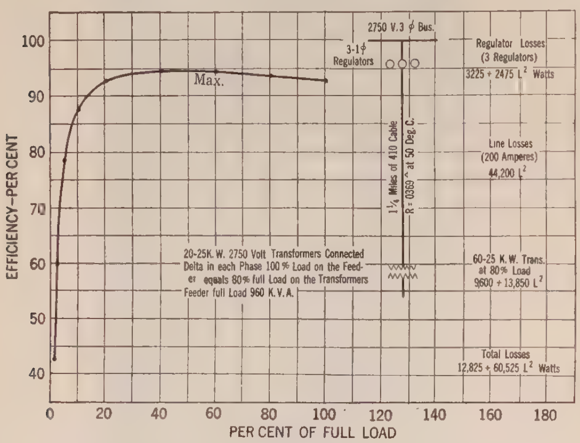

Fig. 4—Distribution Feeder Efficiency from Substation Bus to Distribution Transformer Secondary

service. Connection with the distribution transformers is made at the bottom. (In this case with external reactors in series). The network connections are at the top of the switch through a link fuse. Most of the essential elements are more clearly shown in this figure than in Figs. 2 and 3 which are illustrations of actual installations. The switch has been tested for manhole operation. All of the switches in service to date, however, have been in waterproof vaults.

It is the practise to cut out one or more of the four feeders supplying this service at different times during the day, depending upon the loading conditions. It is not possible to obtain full economy owing to the limited size of the present installation and the necessity of keeping at least two feeders always in service.

Fig. 4 shows the calculated efficiency curve of a radial feeder and its distribution transformers. Dielectric losses and secondary network copper losses are not included. It is evident that maximum efficiency point is about one-half full load kv-a. As long as there are feeders out of service it is desirable to keep the load on feeders in service below the maximum efficiency load indicated, for shorter network cable feeds and to have available capacity in service for reliability of supply.

Fig. 5 is the substation duration curve of the load in kilowatts. It shows the number of hours per year that the load exceeds any given percentage of the peak load. If the capacity of feeders and distribution transformers is assumed to be 20 per cent in excess of the peak (this amount can only be realized in practise on a network) and the kv-a. duration curve of the particular network is assumed to be like Fig. 5, then there is less than 1500 hrs. per year when the feeder loadings will exceed 50 per cent of their capacity, which is assumed above to be the maximum efficiency point. The possible improvement in all-day efficiency is dependent upon the number of feeders supplying the network, but in practise this can fall between eight and twelve on the basis of having two in service at low-load periods.

In the installation of this experimental automatic multiple-feed net-work supply, feeder capacity and amount and arrangement of distribution capacity were made liberal to be certain that all unusual conditions would be met. It was found that with high-reactance transformers it is unnecessary to space distribution transformers so that any particular district is supplied from all the sources of supply, it being sufficient that several sources be adjacent to the district.

The practise of disconnecting feeders at their sources during light load periods has given operating experience and has developed equipment faults which otherwise would have required a long time to develop. Since the principal purpose of this equipment is to give reliability to the supply, it is advantageous to know any switch which will not function on a reversal of energy. When the source is disconnected, the switches are subjected to a relatively small amount of back feed and in case of failure to open, the network will feed back to the source and the particular switch failure can be located on inspection.

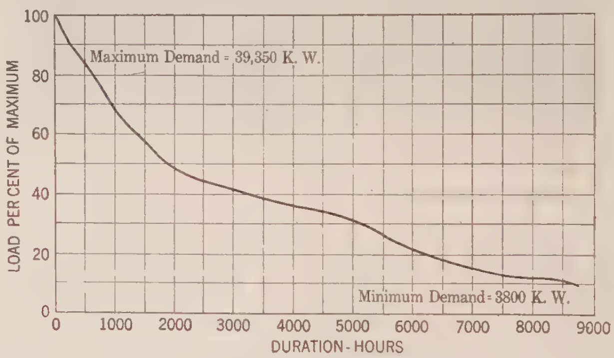

Fig. 5—Duration Curve for U. E. L. & P. Co. 60-Cycle Substations 1923. Data for Wattmeter Readings Taken Each Half Hour Throughout the Year

Since April 12, 1922, the date the network was placed in service, there have been no failures of any kind that affected the service on the network. Three transformers grounded and in each case the feeders were disconnected from their source, which immediately cleared the transformer from the network. Several single and polyphase short-circuit tests were made on the high-voltage feeders in conjunction with tests on some oil circuit breakers. In every case the network supply was continuous and satisfactory. The failures of switches to function with 48,232 total opera-

tions has been 440 (see Table I). Many of the failures are not failures to open, as one-half the total operations are those of closing the switches automatically. Failures to open are in all cases with magnetization of transformers as the load. It is probable that some of these would have functioned if the occasion had been a high-voltage fault. With one or two hand-made sample switches of a new design, much better results have been obtained. A quantity of new switches is being manufactured at present and should be in service early this summer. Many of the faults now occurring will be remedied when it is possible to replace existing equipment on the system and make necessary changes to eliminate the failures which have developed. We expect this class of equipment to give operating results ultimately which will compare with modern railway signal equipment. At present they are inspected once every two weeks. It is believed that except at heavily loaded periods these will be extended to periods of six weeks. The new switches on order and those now in service when reconstructed will equip to capacity 12 radial high-voltage feeders and place in service about six times the present number of switches.

TABLE I.
NETWORK SWITCH OPERATIONS
Number and Type of Failures

Cause of Failure	1922 Apr. 12 to Dec. 31	1923 Jan. 1 to Dec. 31	1924 Jan. 1 to Mar. 22	Total
Sticking of no-voltage relay core	73	53	2	128
Poor contacts on no-voltage relay switch	5	5	2	12
Latch failure	8	3	2	13
Failure of pallet switch	14	7	0	21
Burnt switch leaves	3	0	0	3
Master relay out of adjustment	3	11	2	16
Friction in master relay	27	15	4	46
Dirt on master relay contacts	2	2	0	4
Dirt on relay disc	1	0	0	1
Burnt out closing coil (cause unknown)	4	3	1	8
Burnt out closing coil (caused by faulty no-voltage relay switch)	3	0	0	3
Burnt out closing coil (caused by switch chattering due to faulty latch)	1	0	0	1
Switch chattering	5	0	0	5
Lead to closing coil burnt out	1	0	0	1
Tripping mechanism out of adjustment	0	24	2	26
Causes—undetermined*	130	17	0	147
Causes—Miscellaneous	1	4	0	5
Total failures	281	144	15	440
Total operations	26,451	19,602	2,179	48,232
Per cent failures	1.062	0.734	0.688	0.912

*Includes switch failures from undetermined causes and back feeds on undetermined switches.

Our experience indicates that with this design of underground a-c. low-voltage network, fed from several different sources, the reliability will be the same as the reliability of the sources supplying the various radial high-voltage feeders.

With the increased capacity in low-voltage networks, it will be possible to supply the feeders from two or more separate bus sections so that all the sources will not be affected by faults on one section. A development of this arrangement of operating separate bus sections in multiple makes the supply system take on the character of a network, in that it is possible to transmit the entire capacity of the generators to the low-voltage network, yet the capacity concentrated in any part of the system is a relatively small part of the total capacity. It will, of course, be necessary to equip the generating system with the usual protective devices, although of reduced capacity, compared to that required for a system where paralleling of as many supply points as possible on each bus has the effect of increasing the capacity available at that point.

Appendix A

Voltage Variation Effect on Incandescent Lamp Illumination

Tests were made during 1921 and 1922 of the effect of voltage variation on incandescent lamp illumination to determine possible amount and rate of variation without noticeable flicker. The results depend upon the particular observer, but as the object was to obtain the limits, the observers used for final results were the ones that indicated low values consistently.

A slide wire resistance was used to vary the voltage on the lamps. For instantaneous rates the resistance was cut-in and cut-out of the lamp circuit by means of a knife switch. For other rates of change, apparatus was constructed to move the slider on the resistance at various rates of speed. By measuring the volt drop per inch of resistance, the rate of change in volts per second on the lamp was determined. In order to eliminate the effect of starting and stopping, short-circuiting sleeves were put on the resistance so that only definite changes in voltage could be made from start to finish. The observers were located in a dark room with no extraneous source of light remote from the voltage varying device.

Complete sets of tests were made with 25-watt lamps and with 100-watt lamps.

Tests were made with one lamp 18 in. from the observer's paper.

Another set of readings was taken with two lamps 18 in. apart and 18 in. from the observer's paper. One lamp being flickered and the other being held at constant potential.

Similar readings were taken with the lamp source 8 ft. from the floor with the observer sitting under it in a chair reading.

Tests were made with two lamps 8 ft. from the floor, located 18 in. apart, one being flickered and the other held constant.

Under all of the above conditions, one set of tests was made with decreasing voltage, a second with increasing voltage, and a third with decreasing voltage and then restoring the same to original value.

In Fig. 6 there are four curves showing change in voltage necessary before flicker is noticed in respect to rate of change in voltage per second.

The summary of results of above tests is as follows:

1. That within limits the slower the rate of change, the greater the total voltage change necessary before flicker is noticed.

2. That after a certain point the voltage variation is noticed, no matter how slowly the change is made.

3. That at high intensities the candlepower does not make an appreciable difference, but that at low intensities the flicker is less noticeable, the lower the intensity.

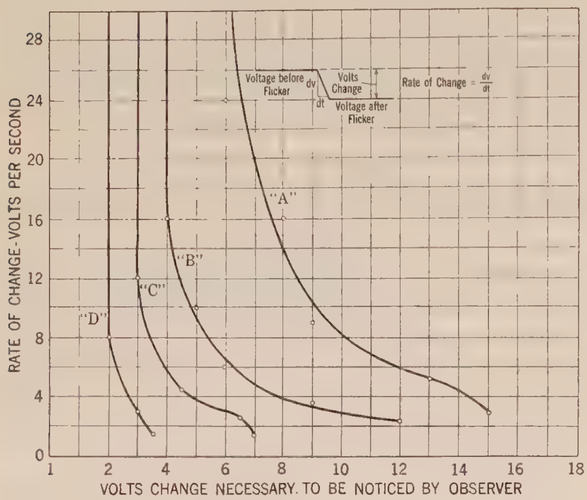

Fig. 6—Incandescent Lamp Flicker Tests, Observer Reading Newspaper

Curve *A*—Two Lamps, 8 ft. from paper and 18 in. apart voltage on one lamp varied.

Curve *B*—Two Lamps, 18 in. from paper and 18 in. apart voltage one lamp varied.

Curve *C*—One Lamp 8 ft. from paper.

Curve *D*—One Lamp 18 in. from paper.

(Mazda Type *B* 115-Volt Lamps were used. The same results were obtained with 25 and 100-Watt Lamps and with increasing and decreasing voltage).

4. The greater the distance to the light source, the larger may be the total voltage change before flicker is noticed.

5. That when there is an additional source of light of constant intensity, a greater voltage change is necessary before flicker is noticed.

6. That the same variations are noticed whether the voltage is increasing or decreasing.

7. That when the drop is made instantaneously the same variations are noticed, if the volts are dropped and allowed to remain at the lower value, as when the voltage is dropped and immediately restored.

8. That at rapid rates of change the maximum allowable variations are from two to six volts and at very slow rates of change from four to eighteen volts, depending upon the condition of illumination.

The above results have been found to be in general agreement with the operating experience of several engineers in using lamps on the same circuits with motors. A recent paper "Voltage Fluctuation and Its Effect upon Lighting" by C. A. Williams, before the Pennsylvania Electric Association in Philadelphia, contains considerable data on the subject.

Appendix B

Alternating Current Arc Tests

Single-conductor cables were tested by removing a section of lead and insulation and setting up an arc

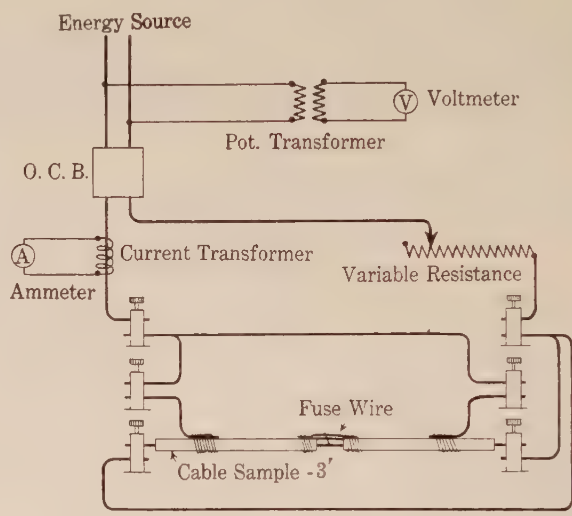

Fig. 7—A-C. Arc Tests. 60-Cycle 800-Kv-a. Motor-Generator Set Direct or with 100-Kv-a. 2750/220-Volt Transformers Connected Parallel-Series

between conductor and sheath with a fuse wire short circuit. The circuit arrangements are shown in Fig. 7, resistance being utilized to limit the arc current for all except the larger values of current used. Results

Fig. 8

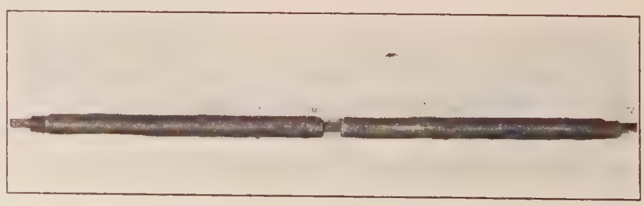

Fig. 9

of tests are plotted in Fig. 8 to 13 inclusive, and characteristic oscillograph results are also shown on following pages.

Comparatively few tests were made at points where

arcs continued, as it was attempted to define the highest values where they would not persist beyond the first few cycles. One set of tests was made on d-c., which

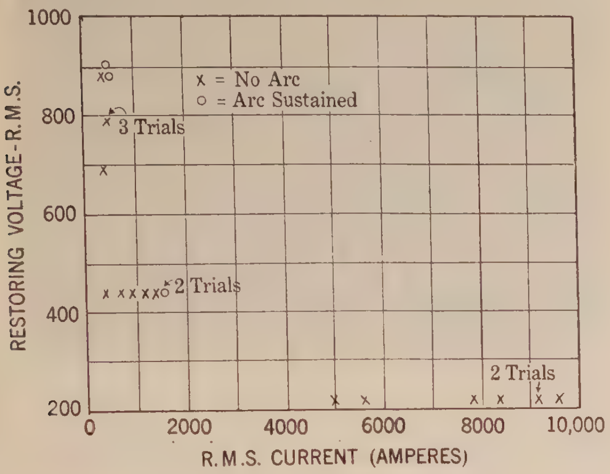

Fig. 10—A-C. Arc Data. 4/0 Cable 6/32 In. Rubber 1/8 In. Lead

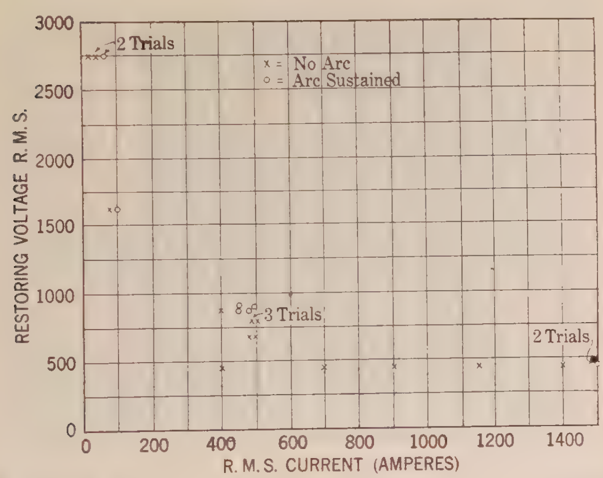

Fig. 11—A-C. Arc Data. 4/0 Cable 6/32 In. Rubber 1/8 In. Lead

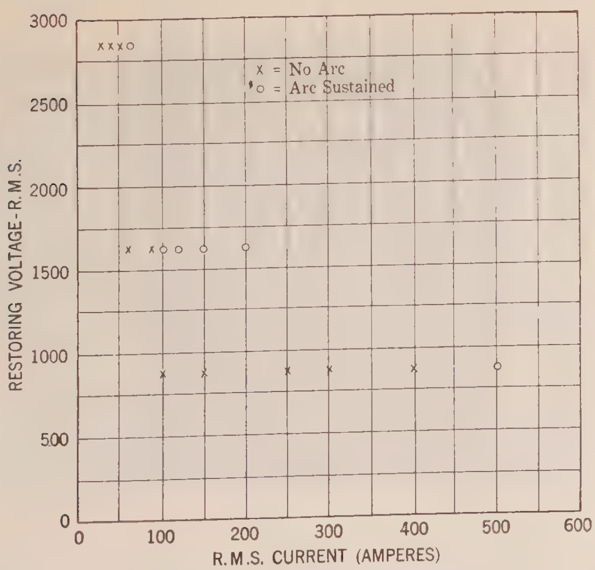

Fig. 12—A-C. Arc Data. No. 3 Cable 6/32 In. Rubber 1/8 In. Lead

showed similar characteristics, although the voltage values were considerably reduced. (Fig. 14).

Appendix C

Self Protecting A. C. Network

When cables are subject to solid short circuits they heat up to an ultimate limit where the copper melts,

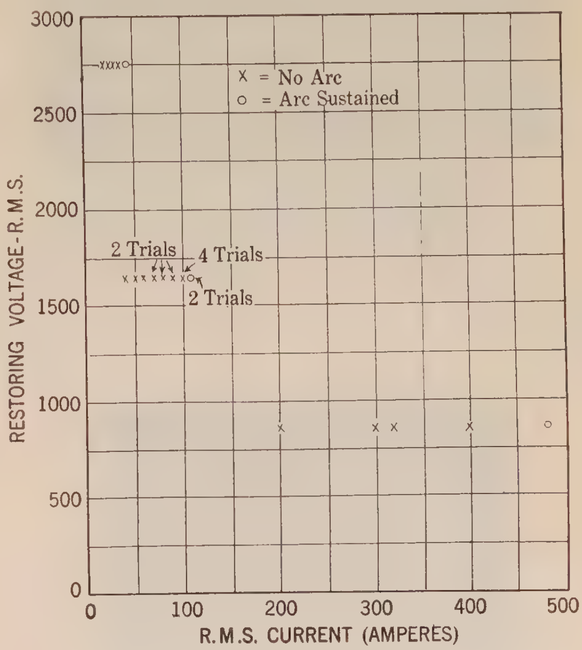

Fig. 13—A-C. Arc Data. No. 3 Cable 9/32 In. Paper 1/8 In. Lead

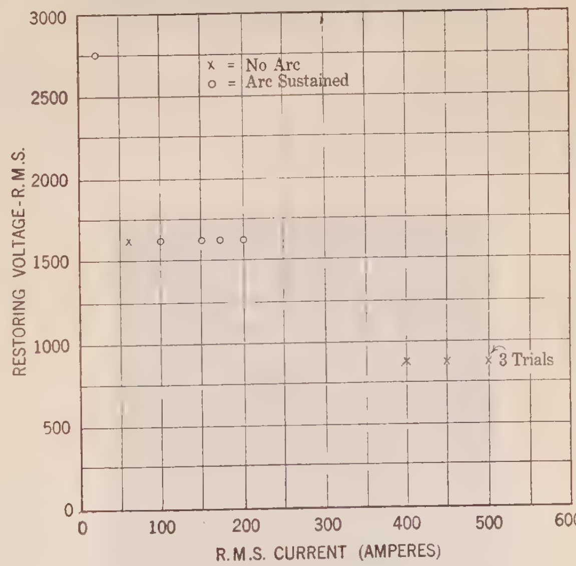

Fig. 14—A-C. Arc Data. 80,000 Cir. Mil Cable 3/32 In. Rubber 3/32 In. Lead

provided there is a sufficient potential drop maintained across the shorted conductors. This potential drop is a function of time, which, for fusing in less than one minute, is dependent upon time only, irrespective of copper cross section; while for time of fusing of over one minute, insulation thickness and overall diameter of

OSCILLOGRAMS—Source of Supply, 800-Kv-a., 60-Cycle Motor Generator Set

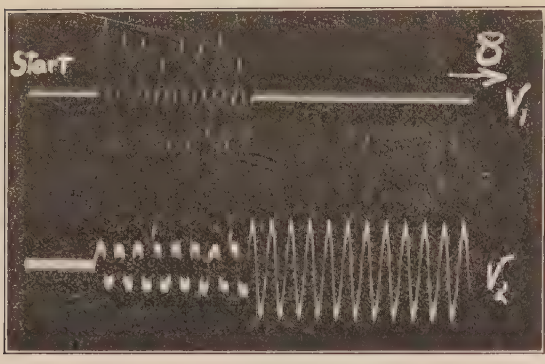

FIG. 15—4/0 CABLE—6/32 IN. RUBBER AND 1/8 IN. LEAD

Short-circuit on 1-100 kv-a. transformer. 3 per cent internal and 3 per cent external impedance. Open circuit voltage 220 r. m. s., 292 max. arc voltage 133 max. arc held 7½ cycles. At beginning of third, fifth and seventh cycles and middle of fifth cycle, current does not flow until voltage is near maximum value and does not reach full value as voltage rapidly diminishes. Current is in phase with voltage. Max. value of current 7100 amperes.

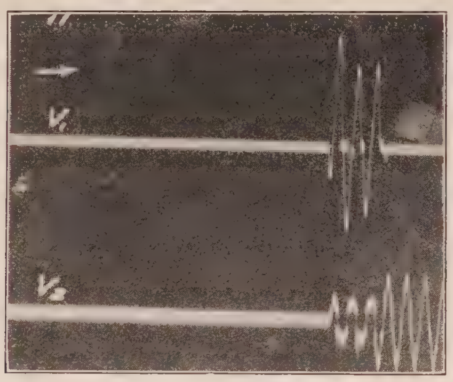

FIG. 16—4/0 CABLE—6/32 IN. RUBBER AND 1/8 IN. LEAD

Short circuit on one 100-kv-a. transformer, 3 per cent internal impedance. Open circuit voltage 220 r. m. s., 293 max. Arc voltage 117 max. arc held 3 cycles and tried to reestablish on second half of fourth cycle. Max. value of current 11,100 amperes.

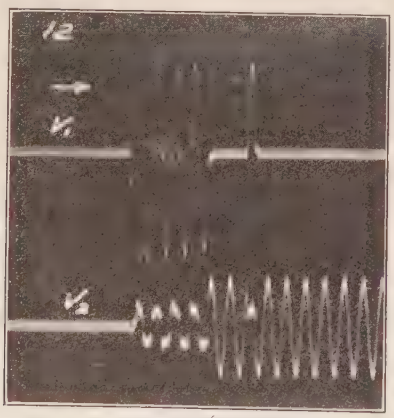

FIG. 17—4/0 CABLE—6/32 IN. RUBBER AND 1/8 IN. LEAD; COVERED WITH 2-FT. PIECE OF 3-IN. FIBRE CONDUIT AND RAGS STUFFED IN ENDS

Short circuit on one 100-kv-a. transformer, 3 per cent internal impedance. Open circuit voltage 220 r. m. s., 300 max. arc voltage 117 max. arc held 4½ cycles and tried to reestablish on seventh cycle. Max. value of current 11,850 amperes. Probably the attempt to reestablish was due to being in conduit and took place before same was fully cleared of gas by the explosive force.

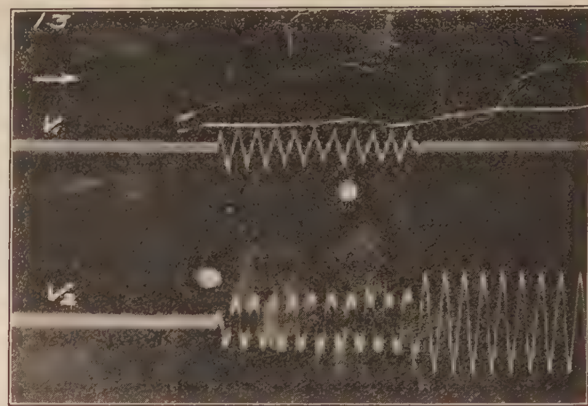

FIG. 18—4/0 CABLE, 6/32 IN. RUBBER AND 1/8 IN. LEAD

Short circuit on two 100-kv-a. transformers in parallel; 3 per cent internal impedance. Open circuit voltage 220 r. m. s., 300 max. arc voltage 150 max. arc held 11 cycles. Max. value of current 13,100 amperes. Shows the cessation of current at zero potential until voltage has risen enough to restore arc.

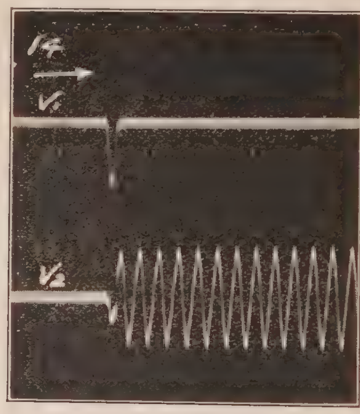

FIG. 19—SAME AS FIG. 18 EXCEPT CABLE SAMPLE WAS COVERED WITH CONDUIT AS FOR FIG. 16. EXPLOSIVE FORCE CLEARED CONDUIT ALMOST INSTANTLY AND ARC HELD 1/2 CYCLE

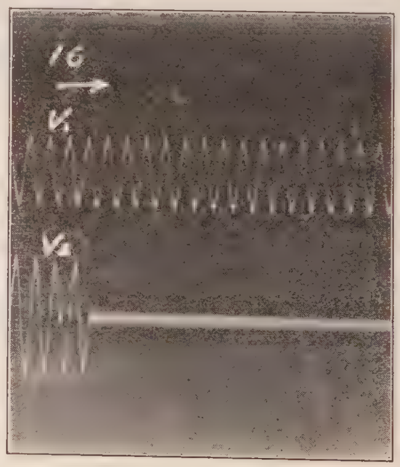

FIG. 20—4/0 CABLE—6/32 IN. RUBBER AND 1/8 IN. LEAD

Open circuit voltage 900 r. m. s., 1300 max. Resistance to limit current to 450 amperes r. m. s. Max. current when arcing 782 amperes. Arc held until switch was opened and film shows end of current wave, which is fairly smooth and indicates that arc was well sustained.

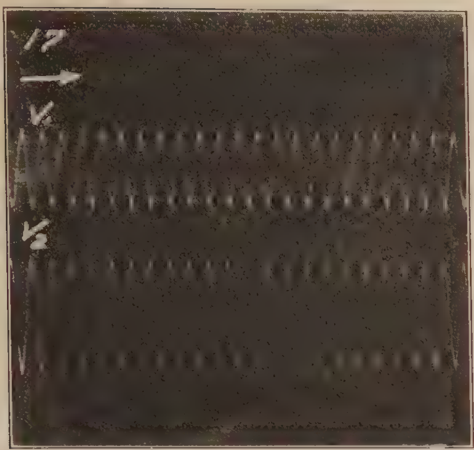

Fig. 21—4/0 Cable—6/32 In. Rubber and 1/8 In. Lead

Open circuit voltage 787 r. m. s., 1215 max. current-limiting resistance to limit current to 480 amperes r. m. s. Max. current when arcing 748 amperes. This film was taken in middle of arc time which was extinguished by opening switch. Arc probably would have died out, as near the end of the film the current stays at zero value for part of the cycle (on several cycles).

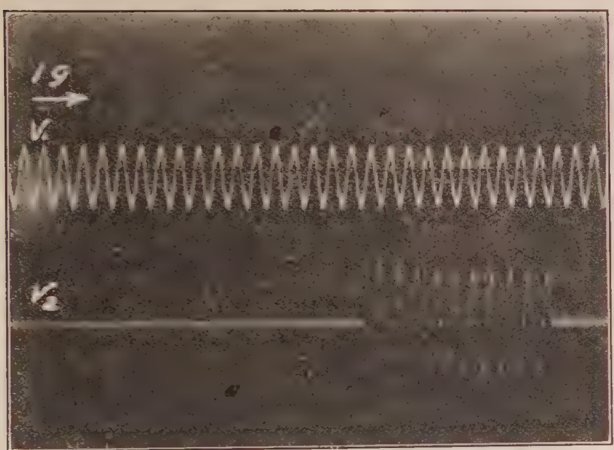

Fig. 22—4/0 Cable—6/32 In. Rubber and 1/8 In. Lead

Open circuit voltage 687 r. m. s., 1000 max. resistance to limit current to 490 amperes r. m. s. Max. current when arcing 765 amperes. Arc held 10 cycles under these conditions.

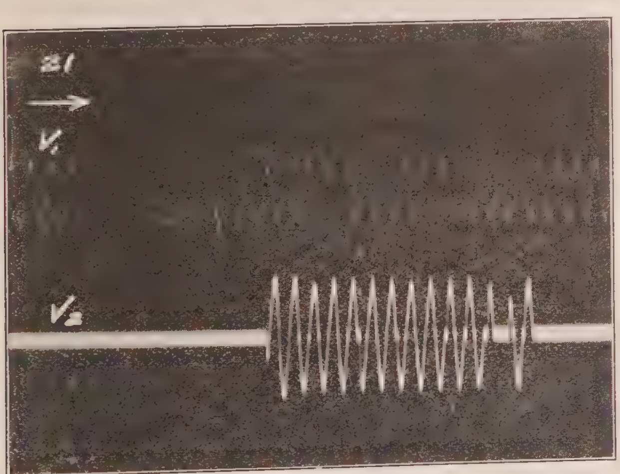

Fig. 23—4/0 Cable—6/32 In. Rubber and 1/8 In. Lead

Open circuit voltage 780 r. m. s., 1100 max. Resistance to limit current to 500 amperes r. m. s. max. current when arcing 803 amperes. Shows arc attempting to break at zero value of current and voltage. Gaps of more than ½ cycle are indicated.

cable become additional factors. These two latter factors show little divergence, for the general cable

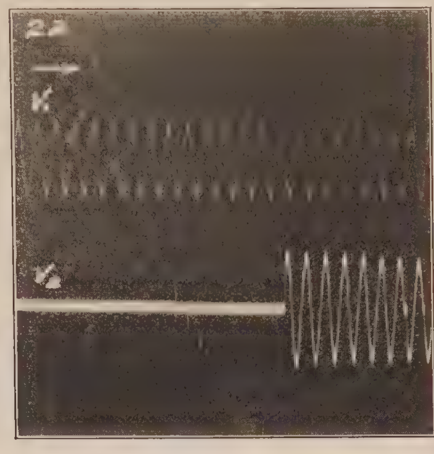

Fig. 24—4/0 Cable—6/32 In. Rubber and 1/8 In. Lead

Open circuit voltage 880 r. m. s., 1210 max. resistance to limit current to 480 amperes r. m. s. max. current when arcing 765 amperes. This arc held and switch was opened finally. Shows sputtering of arc and attempts to break. Voltage was sufficient to keep on restoring arc. Indentation in voltage waves are where arc restores suddenly.

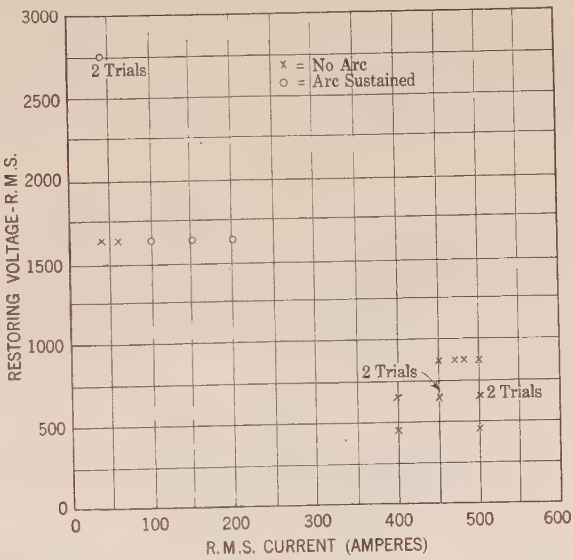

Fig. 25—A-C. Arc Data. 40,000 Cir. Mil Cable 3/32 In. Rubber 3/32 In. Lead

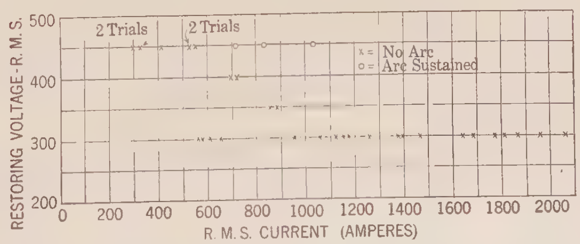

Fig. 26—D-C. Arc Data No. 4/0 Cable 6/32 In. Rubber 1/8 In. Lead

sizes which would be used in networks. Thermal capacity curves for this cable are shown in Fig. 27.

Since a minimum limit of six volts per 100 ft. is required to melt soldered joints and break down the

chemical structure of ordinary insulating material, this fixes the maximum transformer spacing. The choice of minimum voltage gradient in the designing of a self-clearing network will lie between the above value and 24 volts per 100 ft., which is the minimum voltage gradient required to fuse the copper conductors.

The maximum transformer spacing for a simple network is numerically equal to the phase voltage of the network, divided by the chosen voltage gradient.[1] This spacing may be increased by making the network more complex, for example, the transformer spacing may be doubled by employing parallel maines tied together midway between transformer points. The configuration of the network grid is fixed usually by the arrangement of streets in the district. It is desirable to have transformer spacing and junction points of the grid coincide for the purpose of economy and regulation.

Determination of the maximum transformer size

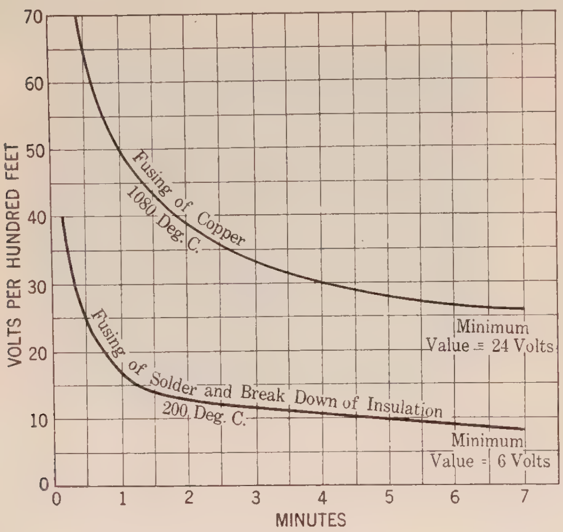

Fig. 27—Voltage Required to Clear Short Circuits on 200,000-500,000 Cir. Mil Cables

can be made from the load density and maximum spacing.

In order that destruction of copper under network short circuit may occur in the cable and not in the transformer, it is desirable that fusing current of the cable shall not be more than twice the current which can be carried safely for the required time by the adjacent transformer bank.

The maximum limits of transformer size, spacing and cable size are thus established for a self-protecting network.

Cross section of the cables may then be reduced to a size which will give the allowable regulation with the maximum instantaneous increment of current likely to be obtained. Transformer size may then be reduced, with the accompanying reduction in spacing and cable size until an economic balance is reached between transformers and cable, keeping in mind the ultimate growth in the district. Any reduction made in transformer size and spacing or in cable size will not affect the ability of the network to burn off short circuits.

For the district of Manhattan where the experimental network installation was installed the system contemplated 200,000-c. m. single-conductor cables on both sides of all streets, transformers located at each street intersection, and a maximum grid spacing of 880 ft. in one direction and 280 ft. in the other. It was found that with 10 per cent reactance transformers, at least 25 kv-a. per phase would be required to give sufficient current to maintain more than the required six-volt drop for the extreme case of secondary short-circuit. This is considerably lower than the load density of the district requires.

1. On the basis of maintaining constant secondary voltage at transformers.

THE AMPERE TROUGH EXPERIMENT*

ITS EXPLANATION BY THE USUAL ELECTROMAGNETIC LAWS

In the *Journal* of the Franklin Inst. p. 559, Nov. 1921, Carl Hering describes a modification of the classical Ampere trough experiment for whose explanation he believes the usual electromagnetic laws inadequate. The present paper gives detailed experimental and mathematical analysis of this circuit. The circuit is a wire rectangle *A B C D*, 70 cm long, 25 cm wide, interrupted at the center of one long side, *C D* by troughs of mercury, of rectangular cross section, 4 cm by 1 cm deep, perpendicular to *C D* and spaced 5 cm between centers. With the bridge close to *C D* on either side, there is no perceptible force. With the bridge inside the rectangle and 2 cm to 20 cm from *C D*, the force is away from *C D*. With the bridge inside the rectangle and more than 20 cm from *C D*, the force is *toward C D*. With the bridge outside the rectangle and more than 2 cm from *C D*, the force is *away* from *C D*. If the length of conductor in the circuit be increased by movement of the bridge, an increase of inductance is possible even with a decrease of the area enclosed by the circuit. Calculation shows a maximum or minimum of inductance in regions where the direction of force changes. The bridge always moves so as to *increase* the inductance. Inductance measurements check the calculated values. Furthermore, analysis of the forces between the bridge and the other elements of the circuit by the usual laws explains the observed movements of the bridge. Recently published results of Morecroft, A. I. E. E., p. 1191, Nov. 1923, confirm these conclusions.—F. W. Grover, J. P. Daz and J. Turnbull, Union College.

*Abstract of a paper presented before the *American Physical Society*, April 25, 1924.

The Cleveland Heights Substation
of the Cleveland Electric Illuminating Company

BY H. L. WALLAU
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Cleveland Electric Illuminating Co., Cleveland, Ohio

***Review of the Subject.**—Originally designed for railway service in small units, the use of the non-attended automatic substations has gradually been extended to substations feeding d-c. networks and a-c. lighting and power distributions of increased capacity and importance.*

They are justified economically up to the point at which the fixed charges and operating costs on the additional equipment required over and above a manually-operated station, equal the costs of attendance.

A description of an a-c. station having an ultimate capacity of 12,000 kw. follows, emphasis being laid upon the more interesting features of design.

An automatic (self-restoring circuit) a-c. substation for the supply of service in a high grade residential suburb of Cleveland, was put in commission in the latter part of 1920 as a manually-operated station, and upon the completion of the installation of the necessary relays, the operators were withdrawn and its operation as a full automatic substation begun toward the latter part of January, 1921.

The operating results obtained at this station have been most gratifying and other stations of this type will be installed in such locations as may warrant them.

Because of the character of the neighborhood in which the substation site was located, it was essential to combine sightliness with utility. To this end, a reinforced concrete building of one story and basement was designed along pleasing architectural lines, and

Fig. 1—View of Substation Building

the outside finished in ornamental stucco. A wall of similar finish was put around the property and ornamental gates installed for the entrance of vehicles and pedestrians. Care was taken to preserve a large elm in front of the station. Fig. 1 shows the exterior of this building and a glimpse of the outdoor transformer installation.

The electrical lay-out is quite simple. 3000-kv-a. transformer banks installed out-of-doors at the rear of the buildings are fed each by an 11-kv. cable circuit of the same capacity. The cable terminates in a three-phase pothead from which the leads are led to the transformer units through an air-break disconnecting switch, the three poles of which are mechanically interconnected and operated simultaneously by manual control from below. Three such banks totalling 9000-kv-a. are now installed. Fig. 2 shows a one-line diagram of connections.

The low-tension sides of the transformers are connected for 2300 volts delta and are led through single-conductor lead-covered cables to oil breakers located in a masonry structure in the rear of the building, which structure also houses the necessary disconnecting switches, current and potential transformers.

Connection is made through these oil switches to each section of the distribution board, of which there are now three; ultimately four will be installed.

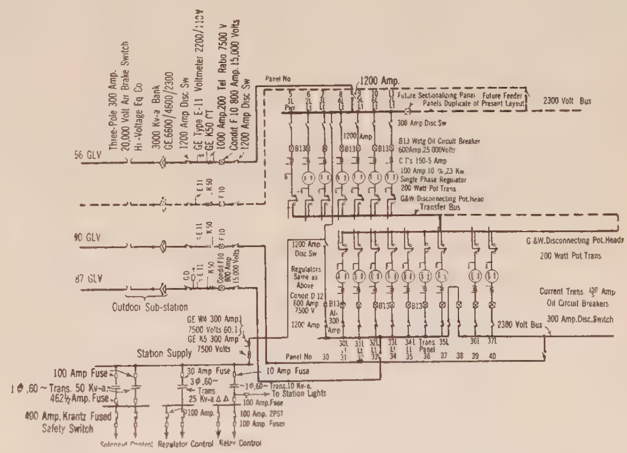

Fig. 2—General Wiring Diagram

The transformers are equipped with watthour meters, wattmeters and maximum demand indicators.

Protection is obtained by means of overload induction type relays on the sending end of the transmission cables and reverse-current relays on the low-tension side of the transformers, thus cutting out a cable and bank as a unit in case of failure of either.

This arrangement has led to the practical elimination of 11-kv. busses, incoming line breakers and breakers on the high side of the transformer banks, reducing space and equipment requirements to a minimum.

Each section of the distribution board has, in addition to a tie panel connecting it to the adjacent section,

To be presented at the Annual Convention of the A. I. E. E., Edgewater Beach, Chicago, Ill., June 23-27, 1924.

seven feeder panels which normally have outgoing circuits connected to them. There is, however, a duplicate spare panel to which any feeder may be transferred when it is desired to inspect the oil breaker or work on any equipment. This transfer is effected by means of a duplicate 4/0 wire bus and single-phase potheads at each panel. Any equipped panel not connected to an outgoing line may be so used, however.

The feeder breakers are 600-ampere, 25,000-volt with

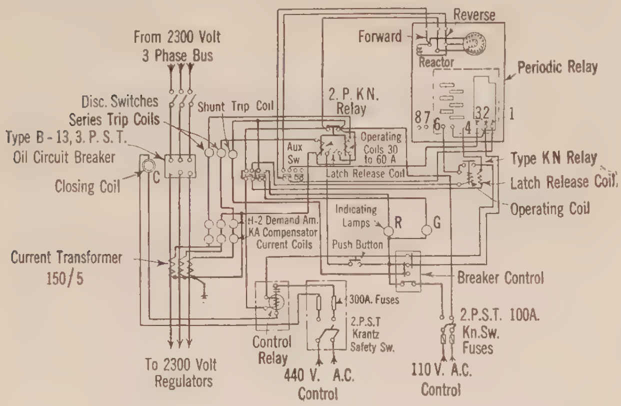

Fig. 3—Wiring Diagram of Self-Restoring Equipment

a rated interrupting capacity of 25,500 arc amperes at 2500 volts. The maximum ultimate short-circuit current has been computed at 28,100 amperes with all sections tied together and a dead short-circuit on the bus.

The timing relay is adjusted for three reclosures at seven-second intervals. In addition, there is a lockout relay set for 30 amperes (900 amperes at 2200 volts)

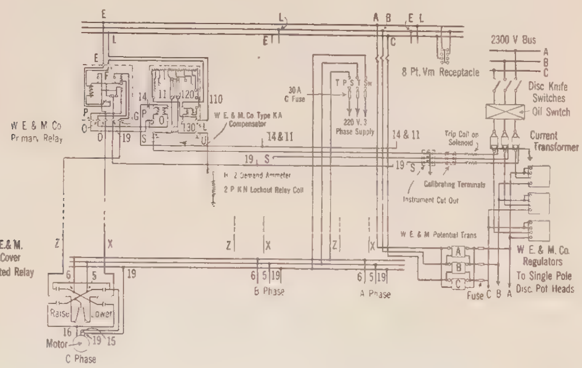

Fig. 4—Wiring Diagram of Feeder Regulator Control

which prevents the reclosing of the feeder breaker upon a short circuit of this or greater magnitude.

Feeders are equipped with compensators controlling motor-operated induction regulators, three single-phase units being used in each circuit. The spare panel also has regulators as part of its permanent equipment.

Each phase of the outgoing circuits is equipped with a thermal demand ammeter to indicate the maximum load carried on each phase, so that overloading of equipment may be guarded against and any necessary circuit balancing taken care of. Fig. 3 shows the wiring diagram for the self-restoring control and Fig. 4 the regulator control wiring. A view of the switchboard is shown in Fig. 5.

The regulators and station supply transformers are located in the basement and housed in cells. These cells are provided with a drain to an oil sump and with a knock-out curb which will prevent flooding the floor with oil, in the event a regulator case should be split in two under a violent short circuit.

Fig. 6 is an illustration of this portion of the installation.

Fig. 5—General View of 2300-Volt Switchboard

All circuits leave the building underground, the cables being trained in vaults on each side of the building which connect to a large manhole in the front.

The station has been designed for a total capacity of 12,000 kv-a., but space is available for a fifth transformer bank, should the load requirement demand it. This would permit an average peak loading of 500 kv-a. each on the 24 feeders eventually to be installed.

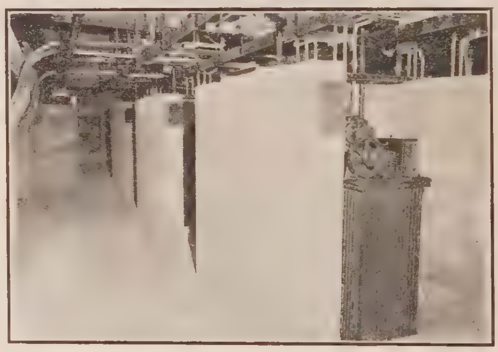

Fig. 6—View of Basement Showing Regulators in Cells

with the fifth bank in reserve. Since the 100-ampere regulators can easily carry a two-hour lighting peak of 125 amperes, no change in equipment will be required to carry 12,000 kv-a. should it be necessary to install the fifth bank previously referred to.

The balance between the cost of operators' wages and the additional fixed charges and maintenance expense, due to the additional equipment installed over that required for a manually operated station, will be reached with the number of circuits planned and will lie between 9000 and 12,000 kv-a. of peak load, depending upon the average peak load carried per feeder.

STANDARD SYMBOLS FOR ELECTRICAL EQUIPMENT OF BUILDINGS

AESC C 10

Approved as an "Tentative American Standard," March 6, 1924.

Developed under procedure of American Engineering Standards Committee

Ceiling Outlet	
Ceiling Outlet (Gas and Electric)	
Ceiling Lamp Receptacle—Specification to Describe Type such as Key, Keyless or Pull Chain	R
Ceiling Outlet for Extensions	E
Ceiling Fan Outlet	
Floor Outlet	
Drop Cord	D
Wall Bracket	
Wall Bracket (Gas and Electric)	
Wall Outlet for Extensions	E
Wall Fan Outlet	
Wall Lamp Receptacle—Specification to Describe Type such as Key, Keyless or Pull Chain	R
Single Convenience Outlet	
Double Convenience Outlet	2
Junction Box	J
Special Purpose Outlet—Lighting, Heating and Power as Described in Specification	
Special Purpose Outlet—Lighting, Heating and Power as Described in Specification	
Special Purpose Outlet—Lighting, Heating and Power as Described in Specification	
Exit Light	
Floor Elbow	O^E
Floor Tee	O^T
Pull Switch	P.S.
Local Switch—Single Pole	S^1
Local Switch—Double Pole	S^2
Local Switch—3 Way	S^3
Local Switch—4 Way	S^4
Automatic Door Switch	S^D
Key Push Button Switch	S^K
Electrolier Switch	S^E
Push Button Switch and Pilot	S^P

Remote Control Push Button Switch	S^R
Tank Switch	T.S.
Motor	
Motor Controller	M.C.
Lighting Panel	
Power Panel	
Heating Panel	
Pull Box	
Cable Supporting Box	
Meter	
Transformer	
Branch Circuit, Run Concealed under Floor Above	
Branch Circuit, Run Exposed	
Branch Circuit, Run Concealed Under Floor	
Feeder Run, Concealed under Floor Above	
Feeder Run, Exposed	
Feeder Run, Concealed under Floor	
Pole Line	
Push Button	
Buzzer	
Bell	
Annunciator	
Interior Telephone	
Public Telephone	
Local Fire Alarm Gong	F
City Fire Alarm Station	
Local Fire Alarm Station	F
Fire Alarm Central Station	F.A.
Speaking Tube	
Nurse's Signal Plug	N

Maid's Plug	M
Horn Outlet	
District Messenger Call	
Clock (Secondary)	
Clock (Master)	
Time Stamp	
Electric Door Opener	
Watchman Station	W
Watchman Central Station Detector	W
Public Telephone—P. B. X. Switchboard	P.B.X.
Interior Telephone Central Switchboard	I.X.
Interconnection Cabinet	
Telephone Cabinet	
Telegraph Cabinet	
Special Outlet for Signal System as Described in Specification	
Battery	
Signal Wires in Conduit Concealed Under Floor	
Signal Wires in Conduit Concealed under Floor Above	
This Character Marked on Tap Circuits Indicates 2 No. 14 Conductors in ½-in. Conduit (see note)	
3 No. 14 Conductors in ½-in. Conduit	
4 No. 14 Conductors in ¾-in. Conduit Unless Marked ½-in.	
5 No. 14 Conductors in ¾-in. Conduit	
6 No. 14 Conductors in 1-in. Conduit Unless Marked ¾-in.	
7 No. 14 Conductors in 1-in. Conduit	
8 No. 14 Conductors in 1-in. Conduit	

Note—If larger conductors than Number 14 are used, use the same symbols and mark the conductor and conduit size on the run.

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Magnetic and Electrical Properties of the Ternery Alloys FE-SI-C.*

BY T. D. YENSEN
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Review of the Subject.—*The variations in the magnetic properties of iron and iron-alloys, even of supposedly constant composition, have been puzzling to the users and investigators of ferro-magnetic materials ever since the introduction of such materials for electrical apparatus. The author started to investigate this problem over ten years ago at the University of Illinois, and has continued it at the Westinghouse Research Laboratory since 1916, concentrating on iron and iron-silicon alloys. While the results obtained do not eliminate 100 per cent of the difficulties, they go a long way in that direction.*

It has been found that carbon is largely responsible for the variations, because of the fact that amounts so small as previously to be regarded as traces—less than 0.01 per cent—remain dissolved in the iron in the solid state, even after slow cooling, and have a tremendous influence on the magnetic properties. Of much less effect is carbon precipitated as pearlite, free cementite and graphite, the effect being in the order named. If the effect of dissolved carbon be represented by 100, the effect of carbon as pearlite is 16.5, of carbon as Fe_3C *2.25, and of carbon as graphite nearly nil. The form assumed by carbon—aside from the carbon in solution—depends largely on the silicon content, and can best be explained by referring to Fig. 9.*

Besides carbon, it has been found that the grain size has a large and definite influence on the magnetic properties, due to the accompanying intercrystalline amorphous cement that may be regarded as an impurity similar to other intercrystalline impurities.

The detrimental effect of sulphur, phosphorous and manganese on pure iron is in the order named, while phosphorous has a beneficial effect on high silicon alloys.

The evidence obtained is to the effect that the increased reluctivity, coercive force, or hysteresis loss, due to carbon and other impurities that are precipitated combined with iron—including in this class the inter-crystalline cement—is caused by the inherent corresponding property of these precipitated impurities.

Regarding the tremendous effect of carbon in solution, it is suggested that this is due to the entering of carbon into the more or less stable equilibrium arrangement of the ferro-magnetic structure, upsetting this equilibrium arrangement.

I. Introduction

THE superiority of Si-steel over plain iron for magnetic purposes was discovered by Hadfield in 1899.[1]

The steel, containing 4 per cent silicon, was first used commercially in England in 1903[2] and immediately proved a decided success. The first patent in the United States[3] on silicon steel was granted Hadfield on December 1, 1903, but it was not until 1906 that the first transformer was built in this country using the new steel. Since that time silicon steel has been used almost exclusively for transformers, both here and abroad, with an enormous saving in energy, and it is still without a competitor, in spite of the many investigations[4] made for the purpose of discovering one. However, the 4 per cent silicon steel of today is much better, magnetically, than Hadfield's original steel, due to improvements in manufacturing processes, in raw materials and in methods of heat treatment. Roughly speaking, the hysteresis loss is only one-half and the maximum permeability is at least twice that of Hadfield's steel, but these improvements were largely accomplished prior to 1910. During the last ten years the average improvement, as far as can be gathered, has been approximately 1 per cent per year, and this improvement has been due more to minor improvements in the heat-treatment than to refinements in composition.

Resume of Previous Investigations

The effect of the ordinary impurities on the magnetic properties of iron and iron alloys has not to any great extent formed the main object of systematic scientific investigations. The most probable reason for this is that the factors influencing the magnetic properties are too numerous and were not sufficiently well known to enable the investigators to eliminate the undesirable variables. The objects have rather been to determine the magnetic properties of alloys of iron with elements that will, or may, bestow decidedly new and useful properties upon the iron, and to disregard the effect of such incidental impurities as usually occur in commercially pure iron of the best grades. Hadfield,[5] for example, used Swedish charcoal iron as the base for his investigations and prepared his alloys under commercial conditions. Burgess and Aston[6] on the other hand attempted to get away from this uncertainty and were the first to use electrolytic iron as the base for their alloys. Unfortunately, however, the prepara-

1. Barrett, Brown & Hadfield; *Sci. Trans.*, Royal Dublin Soc. VII, Ser. 2, part 4, January, 1900.

Journal Inst. Elec. Engrs., Vol. 31, 674 (1902).

2. Hadfield: History of the Metallurgy of Iron and Steel, *Proc.* Inst. Mech. Engrs., February, 8, 1915, p. 332.

Yensen: The Development of Magnetic Materials, *Elec. Journal* 18, p. 93, March, 1921.

3. U. S. Patent No. 745, 829.

4. See: Trans. A. I. E. E. 34, p. 2455 *et seq.* Oct. 1915, *Historical Review*, Bull's 72 and 83. Eng. Exp. Stn. Univ. of Ill., Historical Reviews.

Abridgement of paper presented at the A. I. E. E. Midwinter Convention, Philadelphia, Pa., February 5, 1924. Complete copies available to members on request.

*Owing to the publication of this paper with incorrect illustrations in the May Journal it is repeated with corrections in this issue.

5. Barrett, Brown & Hadfield: *Sci. Trans.*, Royal Dublin Soc. VII. Ser. 2, p. 4, January, 1900.

Journal Inst. Elec. Engrs. 31, p. 674, (1902).

6. *Trans. Am. Electrochem.* Soc. XV. p. 369, (1909). *Chem. & Met. Engr.*, January, February, March, April, 1910.

tions were made under conditions (a Hoskins carbon plate furnace) that reintroduced carbon in varying amounts into their alloys and they consequently lost the advantage they had in using a pure base. When the writer started his investigations in 1912 he took advantage of the results of Burgess and Aston and prepared his alloys in a vacuum furnace in such a way that carbon was further eliminated rather than reintroduced, with the result[7] that the magnetic properties obtained, both for pure iron and for iron-silicon alloys, were far superior to those obtained by previous investigators. The results for pure iron were later confirmed by Gumlich, using Fischer electrolytic iron and vacuum treatment.[8]

In these cases, the efforts were concentrated on eliminating and on keeping away the impurities, but in spite of these efforts it was impossible to obtain consistent results and to duplicate results. Not having control over some of the most important factors, and, what was worse, not even knowing what they were, it was evidently useless to attempt to determine the effect of impurities that might produce changes far less than the changes caused by the uncontrollable impurities. Aside from the usual impurities, the question of grain size enters as an important factor affecting the magnetic properties. Ruder has found[9] in the case of silicon steel that the larger the grain size the better the magnetic properties; he also showed how the grain size could be increased, by cold deformation followed by high-temperature annealing, without, however, being able definitely to control it.

Preliminary Work

When, in 1916, the writer transferred his activities to the Research Laboratory of the Westinghouse Company and there tried to duplicate the results previously obtained at the University of Illinois, difficulties were encountered. The results for pure iron checked fairly well but not so for the iron-silicon alloys. The magnetic properties were generally very much inferior and the more so, the higher the silicon content; furthermore, the results varied depending upon the grade of silicon used, in spite of the fact that chemical analysis of the alloys revealed no consistent differences. After a great deal of experimentation on 4 per cent Fe-Si alloys, it was found that annealing under oxidizing conditions at a temperature of 950, 1100 deg. greatly improved the magnetic properties, while annealing in vacuum, hydrogen or nitrogen had no such beneficial effect. By applying this method of heat treatment to the original series of Fe-Si alloys, it was found that all of the alloys were susceptible to the treatment. Some responded very quickly (an hour or two at 1100 deg.) while others were much more resistant (requiring 8 to 10 hrs.) but in all cases, the maximum permeability reached 20,000-35,000 and the hysteresis loss 400-550 ergs per cu. cm. per cycle for $B = 10{,}000$ gauss. Furthermore, it was found that commercial 2 and 4 per cent silicon steels could be improved to nearly the same extent as the laboratory prepared alloys. Analysis of the gases given off during the annealing confirmed the suspicion that carbon was being eliminated and quantitative tests revealed some relationship between the magnetic properties and the amount of carbon eliminated. It was concluded that elimination of carbon was the cause of the improvements, although direct evidence in the way of chemical analysis of the annealed test pieces was not yet obtainable for the reason that the methods available were not sufficiently accurate for this purpose, bearing in mind that 0.05 per cent means high carbon. On account of the great importance attributed to carbon a new method was developed for carbon analysis[10] whereby the sample to be analyzed could be heated first to 600 deg. cent. in vacuum and then to 1100 deg. in oxygen, and the resulting CO_2 frozen out in a liquid air trap and measured by the pressure exerted when evaporated into a known evacuated volume. An accuracy of ± 0.0001 per cent was obtainable by this method and this furnished the means for getting the desired data.

A number of samples of 2 per cent and 4 per cent silicon steels variously decarbonized, were tested and analyzed for carbon. The results completely verified the expectations, the curves for hysteresis loss vs. carbon content having the equation.

$$W_h = 5370 \times C^{.425} \tag{1}$$

for 4 per cent Si steel, and

$$W_h = 9650 \times C^{.493} \tag{2}$$

for 2 per cent Si steel.

These equations forming the first approximation to the true relationship between the magnetic properties and carbon, would, if correct for all carbon contents, lead to the startling conclusion that zero carbon should correspond to zero hysteresis loss and that carbon is the only factor affecting the magnetic properties, as none of the other impurities, nor the structural characteristics, was considered in plotting the above data. Before drawing such sweeping conclusions, however, it

7. Univ. of Ill., *Engr. Exp. Sta.*, Bull's 72, 77, 83, 95, 1914-17.

8. Wissenschaftliche Abhandlungen der Physikal. *Tech. Reichsanstalt*, Berlin, 1915-18.

ETZ. 36, pp. 675-77, 691-94 (1915).

Phys. Zeitschr. 19, pp. 434-36 (1918).

ETZ. Nos. 26 & 27 (1919).

Stahl u. Eisen, 41, p. 1249-54 (1921).

For a rod sample of electrolytic iron cut from a cathode sheet and annealed in a vacuum furnace at 1000 deg. cent. Gumlich obtained the very low coercive force of 0.115 gilberts/cm. after subjecting it to a magnetizing force of $H = 150$; a value that has not been obtained for fused electrolytic iron. However, a value of $H_c = 0.10$ was obtained by the writer in 1915 for ring samples of 3.0 per cent Fe-Si Alloys. (See: University of Illinois *Eng. Exp. Sta. Bulletin* No. 83, p. 67, Table 13, or Trans. A. I. E. E., Vol. 34, p. 2664, Table 10).

9. A. I. M. E. *Trans.* 1913, p. 2805.

10. Carbon in Iron, *Trans.*, Am. Electrochem. Soc. 37, p. 227 (1920).

was deemed advisable to get more reliable data, to use test samples in the form of rings, and to determine carefully the effect of impurities like S, P and Mn.

In order to cover the range of probable silicon contents it was decided to investigate the four series: 0, 2, 4, and 6 per cent silicon. The effect of S, P and Mn was investigated for the 0 and 4 per cent alloys only.

II. Hysteresis Loss

By the method of approximations, using a separate

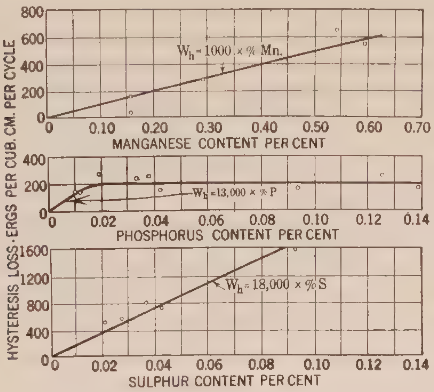

FIG. 1—EFFECT OF Mn, P AND S ON THE HYSTERESIS LOSS OF PURE IRON

set of test rings for each element, the effect of S, P and Mn was determined for 0 per cent Si and for 4 per cent Si alloys, the result being shown in Figs. 1 and 2, and can be expressed by the equations:

For 0 per cent Si: $W_h = 18000 \times S + 13000 \times P + 1000 \times Mn$ (3)

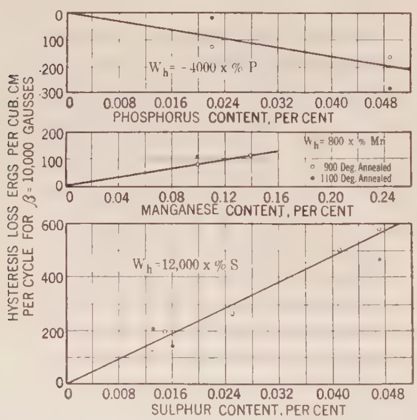

FIG. 2—EFFECT OF Mn, P AND S ON THE HYSTERESIS LOSS OF 4 PER CENT FE-S ALLOYS. ELECTROLYTIC IRON BASE AND GOLDSCHMIDT-THERMIT 91 PER CENT FERRO-SILICON

For 4 per cent Si: $W_h = 12000 \times S - 4000 \times P + 800 \times Mn$ (4)

(Where W_h = hysteresis loss in ergs per cc. per cycle for B = 10000 gauss and S, P, Mn are percentages of these elements.)

By means of these results, the effect of S, P and Mn was eliminated from the total measured hysteresis loss of the main sets of alloys (using equation (3) for 0 and 2 per cent alloys and equation (4) for 4-6 per cent alloys) and thus obtaining the net loss due to carbon and structural characteristics,[11] as shown in Figs. 3 and 4 for 0 per cent Si: in Fig. 5 for 2 per cent Si: in Figs. 6 and 7 for 3.5 and 4 per cent Si; and in Fig. 8 for 5-6 per cent Si. In looking for the possible causes of the large deviations of some of the points from the curve for low carbon contents and bearing in mind in this connection the results obtained by Ruder[12] it was found that for constant low carbon contents ($C < 0.006$ per cent) there appears to be a fairly definite relationship between the hysteresis loss and grain size, expressible by the equation:

$$(N = \text{no. grains per sq. mm.}) \quad (5)$$
$$W_h = 65 \sqrt{N}$$

whereas for higher carbon contents ($C > 0.02$ per cent) the relationship can more nearly be expressed by the equation:

$$W_h = 3 \times N \quad (6)$$

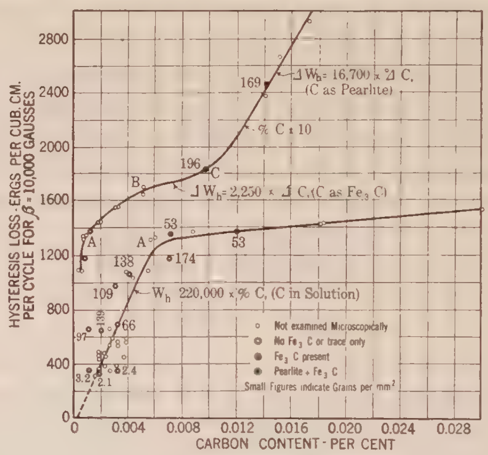

FIG. 3—EFFECT OF CARBON ON THE HYSTERESIS LOSS OF PURE IRON (EFFECT OF GRAIN SIZE NOT ELIMINATED)

By making corrections for grain size in accordance with these equations, it will be found that all the curves for hysteresis loss vs. carbon coincide for $C < 0.008$ per cent, irrespective of the silicon content.

$$W_h = 100000 \times C \quad (7)$$

What, at first, therefore appeared as a difference in the effect of carbon on Fe and Fe-Si alloys has resolved itself into a difference caused by the action of silicon: First, by its action on the grain size, namely, that *without* silicon the normal grain size is small and it is difficult to get large grains, while *with* silicon (4 per cent) the normal grain size is large and small grains can be had only by severe mechanical working; second, by

11. The incidental impurities in the Fe-Si-C alloys were as follows:

S	0.001—0.026 per cent
P	0.002—0.005 per cent
Mn	0.001—0.005 per cent

12. *Loc. Cit.*

the action of silicon on the form of carbon, namely, by precipitating it as graphite instead of as pearlite for carbon contents in excess of about 0.08 per cent. The

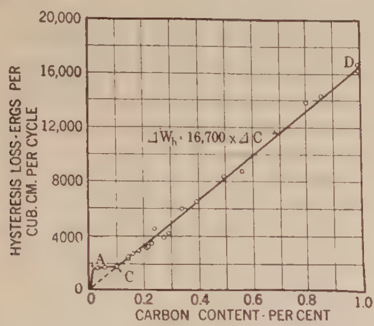

Fig. 4—Effect of Carbon on the Hysteresis Loss of Pure Iron (Effect of Grain Size not Eliminated)

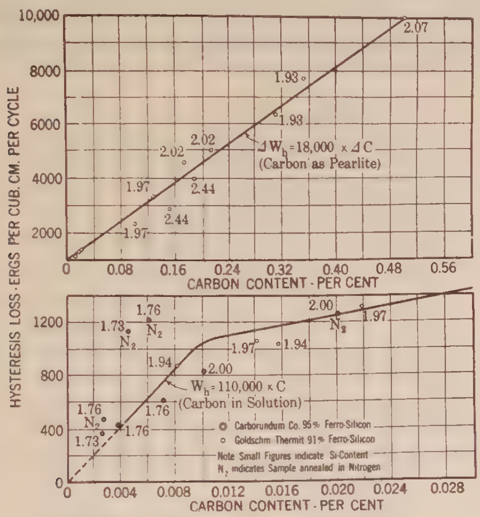

Fig. 5—Hysteresis Loss vs. Carbon Content for 2 Per Cent Fe-Si Alloys (1.73 – 2.44 per Cent Si). Effect of Grain Size not Eliminated

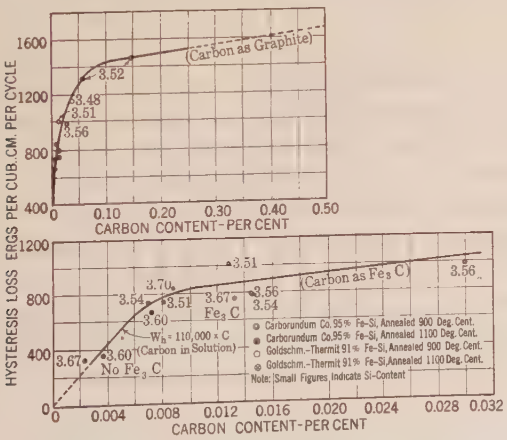

Fig. 6—Hysteresis Loss vs. Carbon Content. 3.5 Per Cent Fe-Si Alloys (3.48 – 3.70 Per Cent Si). Effect of Grain Size not Eliminated

conclusion can, therefore, be drawn that the effect of carbon is the same on unalloyed iron and on 4 per cent Fe-Si alloys and depends only upon the form in which it occurs.

For higher carbon contents, the curves deviate a great deal as seen in Fig. 9, where all the curves have been redrawn for inter-comparison.

Form of Carbon

A great deal of consideration has been given to explaining these peculiar effects of carbon on the hysteresis loss. As the curves developed, it was naturally suggested that the various effects of carbon might be due to different forms in which carbon might exist in the iron. Pearlite being the familiar form in slowly

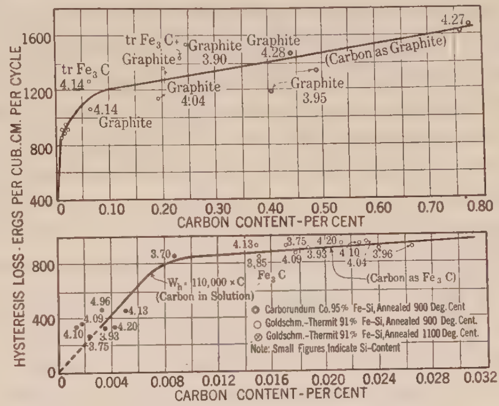

Fig. 7—Hysteresis Loss vs. Carbon Content. 4 Per Cent Fe-Si Alloys (3.70 – 4.30 per Cent Si). Effect of Grain Size not Eliminated

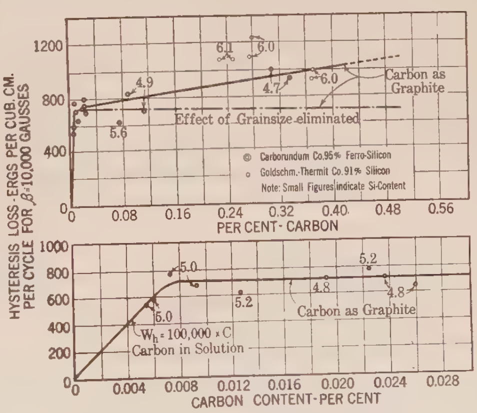

Fig. 8—Hysteresis Loss vs. Carbon Content 5-6 Per Cent Alloys

cooled iron, it was natural to suggest that this was the form in which carbon exists in unalloyed iron in the region 0.1 to 1.0 per cent. It was also thought, since the effect in the region 0.01 to 0.1 per cent was much less, that carbon here might be in the form of Fe_3C unassociated with ferrite. Finally, it was believed, on account of the tremendous effect of carbon in the region below 0.01 per cent, that carbon here must be in solution in the iron, entering into the crystal structure of the iron and distorting the space lattice and upsetting the equilibrium condition upon which the

ferromagnetic properties depend.[13] The slope of the other curves above 0.01 per cent C suggested that for the 2 per cent Si alloys carbon becomes pearlitic immediately above 0.01 per cent instead of passing through the region of free Fe_3C between 0.01 and 0.10 per cent as in the case of 0 per cent Si. The horizontal curves for 4-6 per cent silicon suggested carbon as graphite, an inert material without any effect on the magnetic properties. The curve for 4 per cent Si, in the region 0.01-0.10, coincides with that for 0 per cent Si, indicating that carbon here might be in the form of Fe_3C. At that time the knee of the curves had not been definitely located, but it was known to be in the neighborhood of 0.01 per cent. In the meantime, Mr. N. B. Pilling had been investigating the problem metallographically and it was gratifying to find that his results substantially confirmed the original assumptions. According to his results, carbon is all in solution below 0.005 per cent, *i. e.*, there is no visible trace of precipitated material for lower carbon contents, even by using nitrobenzol etching reagent that attacks Fe_3C without attacking the ferrite, and 1000 diam. magnification. On the other hand, there is a possibility that carbon continues to go into solution to some extent above 0.005 per cent at the same time as it is partly precipitated, perhaps depending upon the annealing conditions. The shape of the curves (Figs. 3-7) indicates that there is no sharp dividing line, and subsequent evidence is to the effect that carbon continues to go into solution to some extent up to 0 02 per cent.

13. Since writing the manuscript for this paper, a very interesting contribution to the subject of solid solutions has been made by Dr. Walter Rosenhain: "Solid Solutions," issued with Mining and Metallurgy, June, 1923, *Trans.* A. I. M. E., 1923, Reprint No. 1250-N. In this paper Dr. Rosenhain explains the "Substitution" theory of solid solutions according to which atoms of various metals are capable of displacing each other in the space lattice of the crystal structure. The amount of solubility and the effect the solute has on the solvent will largely depend upon the relative properties of the atoms of the solute and the solvent. Such substitution would in any case result in some change in the forces between the adjacent atoms of the solvent, and some sort of distortion of the lattice is bound to follow, the more so the greater the difference between the two atoms. Most of the well known phenomena of solid solutions are satisfactorily explained by this theory. In regard to carbon and phosphorus Dr. Rosenhain believes that their atoms are so small compared with those of iron that they can find room in the lattice interstices, but, with effects similar to those of "substitution" atoms. It is readily seen that this theory harmonizes very well with the suggestion given above as to the action of dissolved carbon on the magnetic properties of iron. Dr. Rosenhain purposely avoids discussing the beneficial effect of silicon (and aluminum) on the hysteresis loss of iron, and merely remarks that this effect may be due to a neutralizing effect on the distortions caused by the impurities present. In view of the results given in the present paper it would seem, however, that the beneficial effect of silicon is independent of the impurities, and is due to the causes as stated in the above.

The Question of Grain Size and Intercrystalline Impurities

The question naturally arises: Why should the grain size affect the magnetic properties? There must be something that increases as the grain size decreases, and upon which the hysteresis loss partly depends, or, in other words, that causes an increase in the hysteresis loss over and above that due directly to carbon and other impurities. As far as is known at present, there is only one material that increases as the grain size decreases and this is the amorphous intercrystalline cement, so called. It is, therefore, logical to conclude that there is a definite relation between the amount of this material and the hysteresis loss. It has been shown that the hysteresis loss per unit volume for alloys with carbon in solution is proportional to $\sqrt{N}$. It can also be shown that the amount of the intercrystalline material per unit volume is proportional to

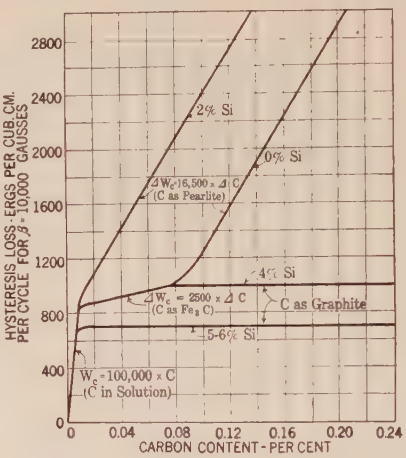

Fig. 9—Effect of Carbon on the Hysteresis Loss of Iron-Silicon Alloys. All other Impurities and Effect of Grain Size Eliminated

$\sqrt{N}$.[14] It follows, therefore, that the hysteresis loss is directly proportional to the amount of the intercrystalline cement, and that the latter acts just like any other intercrystalline impurity, such as Fe_3C, pearlite, FeS, etc.

Another question that remains to be answered is in regard to the mechanism by means of which these intercrystalline impurities increase the hysteresis loss. Does the loss occur in the impurities themselves, or do they increase the loss in the ferrite grains by disturbing

14. Assume that the grains are cubes and that the number of grains per mm.², N, is the same in every direction. Let the thickness of the cement be t mm. No. grains per mm.³ = $N^{3/2}$ and each grain has a volume of $1/N^{3/2}$ mm.³ Each grain is bounded by 6 faces of $1/N$ mm.² Assign one-half the thickness of the intercrystalline cement to each grain, then the volume of cement per grain is one-half $\times 6 \times t \times 1/N = 3\,t/N$ mm.³ Vol. of cement per cu. mm. $= 3\,t/N\; N^{3/2} = 3\,t\,\sqrt{N}$ mm.³ or vol. of cement per unit volume $= 3\,t\,\sqrt{N}$ units.

the uniformity of the flux distribution? Or, do they act merely as inert material, like graphite or air, having relatively speaking, no capacity for conducting a magnetic flux? In favor of the first suggestion speaks the fact that pure pearlite, consisting of Fe_3C and ferrite, has a maximum permeability of 1000 and a hysteresis loss of about 15,000 ergs, 13,500 of which is due to Fe_3C as pearlite (the remainder being due to carbon in solution). This is nearly 15 times the loss for iron saturated with carbon in solution. (0.006 – 0.008 per cent C). Now, pearlite consists of about 13.5 per cent Fe_3C and 86.5 per cent ferrite, and it is difficult to conceive how a reduction in the amount of active ferrite of only 13.5 per cent can possibly increase the flux density in any part to such an extent as to increase the hysteresis loss to 15 times the original value. On the other hand, how can we account for the difference in the effect on the hysteresis loss of Fe_3C as free cementite and of Fe_3C associated with ferrite as finely divided form of pearlite than when it occurs unassociated with the ferrite. It follows from this that the hysteresis loss of Fe_3C must be approximately

$$13500/0.135 = 100{,}000 \text{ ergs per cu. cm. per cycle.}$$

If Fe_3C saturates at a flux density of less than 3000 gauss, as stated by Honda, the flux density in the Fe_3C with 10,000 gauss in the pearlite (obtained by a magnetizing force of 15 gilberts) would be considerably less than 3000 gauss. Suppose, for the sake of calculation, that it is 2500 gauss in the Fe_3C, corresponding to a loss of 100,000 ergs. Applying Steinmetz' coefficient 1.6, the hypothetical loss corresponding to 10,000 gauss would be

$$W_{10} = W_{2.5}\,(10/2.5)^{1.6} = 100{,}000 \times 4^{1.6} = 913{,}000 \text{ ergs.}$$

Now, by regarding Fe_3C as 6.67 per cent carbon dissolved in iron, and applying the formula for dissolved carbon, (**7**) namely,

$$W_h = 100{,}000 \times C$$

the loss for pure Fe_3C for B = 10,000 gauss should be

TABLE I

CALCULATION OF HYSTERESIS LOSS BY MEANS OF COMPOSITION & MICROSTRUCTURE. 4% SI-STEEL

Specimen No.	Gage mils	Heat Treatment: Ann'l. Temp °C	Heat Treatment: Ann'l. Period hrs.	Heat Treatment: Atm.	Composition: Si %	Composition: C %	Composition: S %	Composition: P %	Composition: M_n %	Grain-Size Grains per mm.[2]	Hysteresis Loss (ergs per cub. cm. per cycle for B = 10000), See Figs. 20-23 and Equations: Due to C	Due to S	Due to P	Due to M_n	Due to Grain Size	Total Loss: Calc.	Total Loss: Act.	Difference: ergs	Difference: %
A. 4% Si-Steel Remelted in Vacuo																			
M-203A	125	900	4	12 mm. Hg. 120cc. air/mm.	3.98	.0270	.024	.018	.110	est. 4	895	290	−70	90	10	1215	1245	+ 30	+ 2
204A	"	"	"		4.01	.0287	.020	.019	.120	" 4	900	240	−80	95	10	1150	1180	+ 30	+ 3
203B	"	1100	2		3.98	.0033	.024	.018	.110	" 2	330	290	−70	90	90	730	680	− 50	− 7
204B	"	"	"		4.01	.0030	.020	.019	.120	" 2	300	240	−80	95	90	635	635	0	0
B. 4% Si-Steel Decarbonized by annealing in Fe_3O_4 at 1000°C. Not Rolled																			
M-14-10	375	1000	20	Vac	4.09	.0049	.027	.018	.125	0.12	490	320	−70	100	20	860	775	− 85	−10
30	"	"	"	"	3.95	.0028	.026	.022	.130	est. 0.10	280	310	−90	100	20	620	620	0	0
40	"	"	"	"	3.85	.0033	.036	.021	.130	" 0.10	330	430	−80	100	20	800	877	+ 77	+10
50	"	"	"	"	3.87	.0022	.027	.016	.135	" 0.10	220	320	−60	110	20	610	675	+ 65	+11
60	"	"	"	"	4.06	.0229	.028	.016	.137	" 1.0	890	340	−60	110	3	1283	1242	− 41	− 3
C. 4% Si-Steel. Not decarbonized. Rolled to various Gages in Commercial Mill.																			
M-14-00	375	1000	2	Vac	3.97	.058	.029	.015	.120	est. 37	950	350	−60	95	110	1445	1420	− 25	− 2
01	112	"	"	"	"	.040	"	"	"	act. 145	930	"	"	"	435	1750	1790	+ 40	+ 2
02	56	"	"	"	"	.036	"	"	"	" 75	920	"	"	"	225	1530	1530	0	0
03	28	"	"	"	"	.025	"	"	"	" 189	895	"	"	"	570	1850	1940	+ 90	+ 5
05	14	"	"	"	"	.031	"	"	"	" 225	910	"	"	"	675	1970	1870	−100	− 5

pearlite, the ratio of the former to the latter being as 1 to 7. Furthermore the permeability of Fe_3C, even at 1000 gauss (it saturates at less than 3000 gauss),[15] is so extremely low compared with that of ferrite with 0.008 per cent C at 10,000 gauss that the amount of flux passing through the Fe_3C would be very small, unless the Fe_3C formed a more or less continuous barrier across the flux path.

The only conclusion we can arrive at is, therefore, that there must be a hysteresis loss in the intercrystalline impurities, including in this term the amorphous intercrystalline cement, and that the more or less continuous films formed by these impurities force the flux to pass through them, and furthermore, that more flux passes through the cementite when it occurs in the

15. Honda & Murakauri: Spec. Magnetism of Cementite, Tohoku University, *Sci. Repts.*, 6 p. 23-29, 1917.

$$W_{10} = 100{,}000 \times 6.67 = 667{,}000 \text{ ergs.}$$

While these two results differ considerably (25 per cent) it is interesting to note that by these two different methods of approach, we can arrive at figures for the loss of Fe_3C that are of the same order of magnitude, and that the hysteresis loss of Fe_3C should approach 1,000,000 ergs for a flux density of 10,000 gauss if such a flux density could be reached.

Calculation of Hysteresis Loss

The numerical coefficients for the effect of carbon on the hysteresis loss are given in Fig. 9 and by means of these, in conjunction with equations (**3**), (**4**), (**5**) and (**6**), the hysteresis loss for any Fe-Si-C alloy can be closely calculated from its composition and structural characteristics. Thus, in Table I, three different sets of 4 per cent Si alloys of widely different characteristics

have been tabulated together with their actual hysteresis loss and the loss as calculated from their composition and structure. While the maximum errors amount to $\pm$ 10 per cent it will be noted that the algebraic mean errors for the three sets are $=$ 0.5 per cent, $+$ 1.6 per cent, and 0 per cent respectively, and the mean error for all of the sets is only $+$ 0.43 per cent, showing that by taking the mean for a few samples, the individual errors due to analysis are eliminated and very accurate results are obtained.

III. Coercive Force

While the hysteresis loss is a good criterion of magnetic quality, the coercive force vs. carbon for 0 per cent Si will be given because it serves to tie together the results of the present investigation with those obtained by the German investigators, Gumlich and Steinhaus in the *Physikalish Technischen Reichsanstalt.*[16]

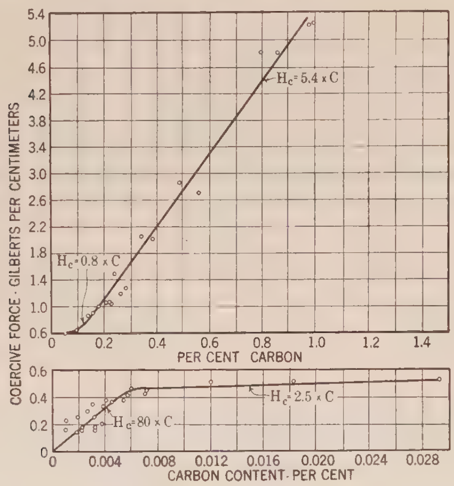

Fig. 10—Coercive Force vs. Carbon Content Fe-C Alloys. (Effect of Grain Size not Eliminated)

In discussing the effect of martensitic carbon, formed by quenching, on the coercive force, H_c, these investigators give the following figures:

0.01 per cent C as pearlite increases H_c by 0.07 gauss

0.01 per cent C as martensite increases H_c by 0.80 gauss

These results were obtained for medium and high carbon contents, as means were not available for analyzing very low carbon contents directly.

The present data in regard to coercive force have been plotted in Fig. 10, giving the following results:

For 0 – 0.006 per cent C: $H_c = 80 \times C$ *i. e.*, 0.01 per cent C produces a coercive force of 0.8 gilberts per cm.

For 0.01 – 0.09 per cent C: $\Delta H_c = 0.8 \times \Delta C$, *i. e.*, 0.01 per cent C increases H_c by 0.008 gilberts per cm.

For 0.10 – 0.90 per cent C: $\Delta H_c = 5.4 \times \Delta C$; *i. e.*, 0.01 per cent C increases H_c by 0.054 gilberts per cm.

Comparing these results with those obtained by Gumlich and Steinhaus, it is seen that our coefficient for carbon contents less than 0.006 per cent is just the same as theirs for martensitic carbon, (carbon in solution) thus confirming again our previous conclusion that carbon in amounts less than 0.006 – 0.008 per cent is all in solution.

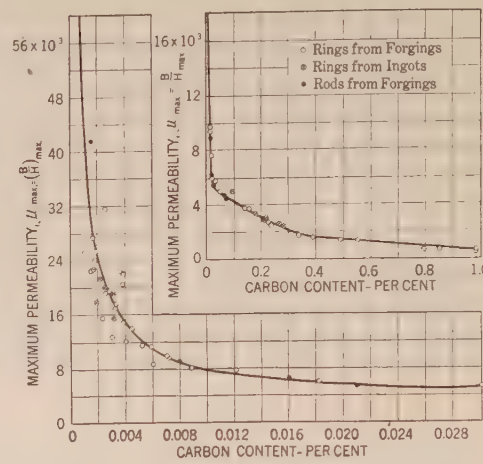

Fig. 11—Maximum Permeability vs. Carbon Content 0 Per Cent Si. No Correction made for Incidental Impurities of Grain Size

In the case of pearlitic carbon, Gumlich and Steinhaus give $\Delta H_c = 7.0 \times \Delta C$, whereas the present data give $\Delta H_c = 5.4 \times \Delta C$. This disagreement is readily understood, if, as is probable, they assumed that all the carbon is precipitated as pearlite by cooling slowly from 900 deg. or above. On this assumption, by drawing a straight or slightly curved line from the origin through the points obtained for H_c corresponding to carbon contents of 0.1 to 1.0 per cent, a coefficient of 7.0 can readily be obtained, but based on the present results this is obviously not correct.

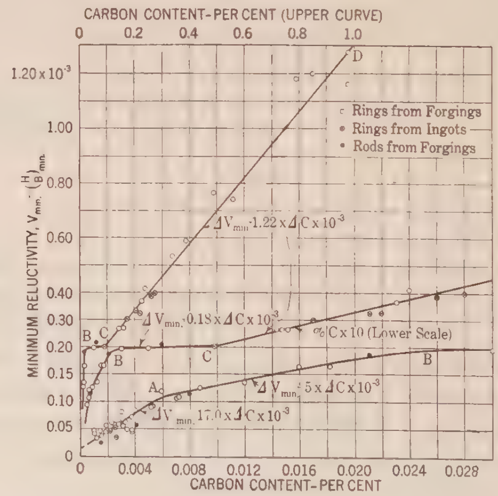

Fig. 12—Minimum Reluctivity ($= 1/\mu_{max}$) vs. Carbon-Content for 0 Per Cent Si. Effect of Incidental Impurities and of Grain Size not Eliminated

16. *ETZ*. 36, pp. 675-77, 691-94, 1915.

IV. Permeability and Reluctivity

The maximum permeability of the Fe-C alloys has been plotted in Fig. 11 with carbon as abscissa. (No correction has been made here for the effect of incidental impurities). The general form of the curve for low and high carbon contents is seen to be that of a rectangular hyperbola, *i. e.*, $\mu_{max} \times C$ = constant. Therefore, by plotting minimum reluctivity ν_{min} $(= 1/\mu_{max})$ instead of μ_{max} a straight line will be obtained $1/\mu_{max} = \nu_{min} = C \times$ constant. In Fig. 12 ν_{min} has been

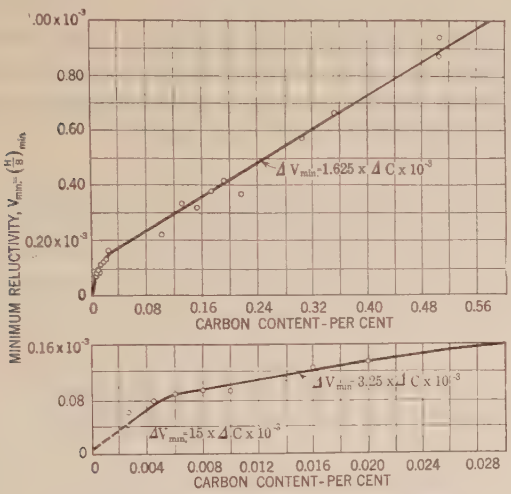

FIG. 13—MINIMUM RELUCTIVITY $(= 1/\mu_{max})$ VS. CARBON CONTENT FOR 2 PER CENT SI. EFFECT OF INCIDENTAL IMPURITIES AND OF GRAIN SIZE NOT ELIMINATED

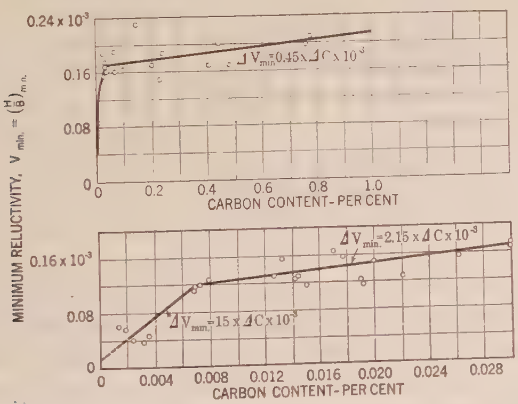

FIG. 14—MINIMUM RELUCTIVITY $(= 1/\mu_{max})$ VS. CARBON CONTENT FOR 4 PER CENT SI. EFFECT OF INCIDENTAL IMPURITIES AND OF GRAIN SIZE NOT ELIMINATED

plotted against per cent C, and it will be seen that the shape of this curve is almost identical with that of the curve for hysteresis loss (Figs. 3 and 4). As a matter of fact, the ratio of the slopes of the various parts of the curve, $O\,A$; $B\,C$: $C\,D$ is 94.5: 1: 6.78 or nearly the same as for the hysteresis loss (98: 1: 7.4) and for the coercive force (100: 1: 7.6), Fig. 10. It must, therefore, be concluded that these three quantities: minimum reluctivity, hysteresis loss, and coercive force are all identical functions of the carbon content and of the state of carbon.

In Figs. 13, 14 and 15, the minimum reluctivity data have been plotted for 2 per cent, 4 per cent and 5-6 per cent Si respectively and in Fig. 16 all the curves thus obtained have been redrawn for comparison. While there are certain minor differences between

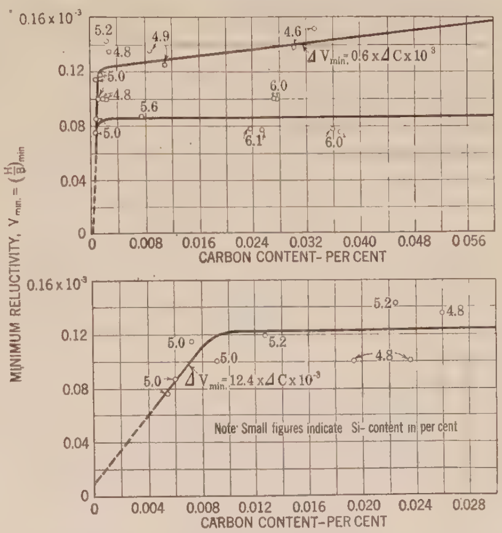

FIG. 15—MINIMUM RELUCTIVITY $(= 1/\mu_{max})$ VS. CARBON CONTENT FOR 5-6 PER CENT SI. EFFECT OF INCIDENTAL IMPURITIES AND OF GRAIN SIZE NOT ELIMINATED

these curves and those for hysteresis loss, the general shape is the same.

In Fig. 17 will be found representative *B-H* curves and other data for 0, 2, 4 and 6 per cent Fe-Si alloys with low carbon contents (0.002 – 0.003 per cent). The maximum permeability is practically the same for

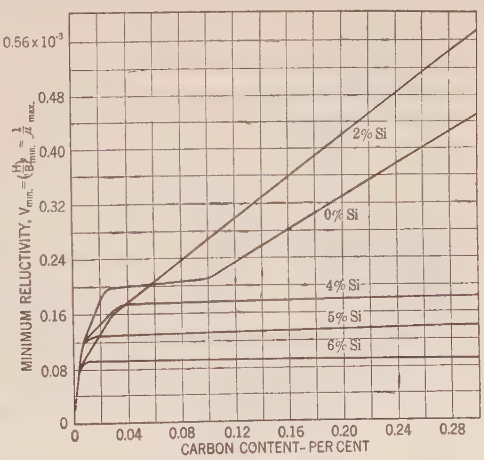

FIG. 16—MINIMUM RELUCTIVITY $(= 1/\mu_{max})$ VS. CARBON CONTENT FOR FE-SI ALLOYS. NO CORRECTION MADE ON ACCOUNT OF INCIDENTAL IMPURITIES AND GRAIN SIZE

all of them, 25,000, but the high induction permeability and saturation value decrease in proportion to the silicon content. The hysteresis loss and coercive force are seen to be higher for the 0 per cent Si than for the other alloys on account of the smaller grain size.

V. Electrical Resistance

1. *Fe-C, Fe-Mn, Fe-S and Fe-P alloys.* The data in regard to electrical resistance have been plotted in Fig. 18, giving the following results:

1. Pure Fe has a resistance of 9.6 microhms per cu. cm. at 20 deg. cent.
2. With addition of *Mn*,
   $\rho = 9.6 + 7 \times Mn.$
3. With addition of *S*,
   $\rho = 9.6 + 12 \times S.$
4. With addition of *P*,
   $\rho = 9.6 + 60 \times P + 3.5 \times (P - .015).$

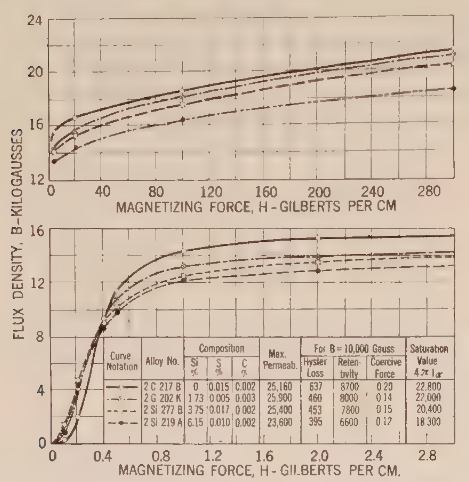

FIG. 17—$B - H$ CURVES FOR 0, 2, 4 AND 6 PER CENT SI ALLOYS. ALL LOW CARBON (0.002 – 0.006 PER CENT)

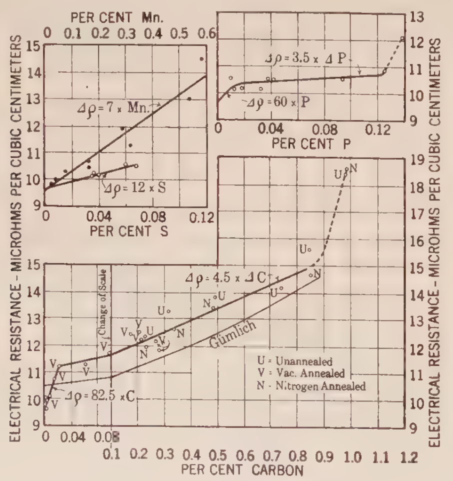

FIG. 18—ELECTRICAL RESISTANCE OF FE-C, FE-MN, FE-S AND FE-P ALLOYS

Upper limits $P = 0.015$ per cent $P = 0.12$ per cent.

5. With addition of *C*,
   $\rho = 9.6 + 82.5 \times C + 4.5 \times (C - 0.02)$

Upper limits $C = 0.02$ per cent $C = 0.85$ per cent.
C in Sol. *C* as Fe_3 C and Pearlite.

Whether the sudden rise above 0.85 per cent C (the eutectoid point) is real or due to an experimental error can not be stated, because 1.0 per cent C was the limit of the carbon content. This same statement must be made in regard to the sudden rise in the curve for Fe-P alloys for $P > 0.12$ per cent. With these exceptions, these curves for electrical resistance in general check those for hysteresis loss as shown in Figs. 1, 2 and 3, and thus serve the useful purpose of confirming the conclusions on p. 8 in regard to the relationship between carbon and iron.

2. *Fe-Si Alloys.* The results obtained for 0-6 per cent Si are shown in Fig. 19.

This curve can be expressed in the form of an equation:

$$\rho = 9.6 + 18.4 \times \text{Si} + 11.1 \times (\text{Si} - 0.35)$$

Upper limits Si = 0.35 per cent Si = 6 per cent that is, the curve is composed of two straight lines with a slight bend at Si = 0.35 per cent.[17]

VI. Summary and Conclusion

1. Of the ordinary impurities in Fe and Fe-Si alloys, carbon has by far the most detrimental effect

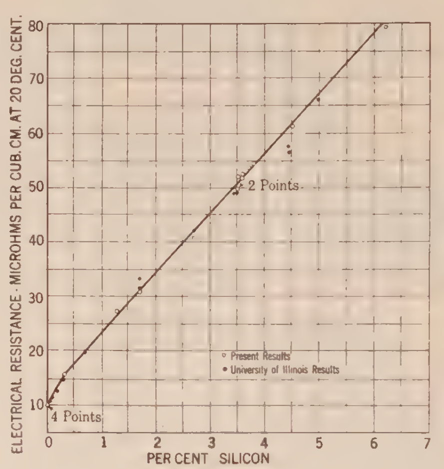

FIG. 19—ELECTRICAL RESISTANCE OF IRON-SILICON ALLOYS

on the magnetic properties, because even in very slowly cooled materials it all exists in solution (martensite) in amounts up to 0.007-0.008 per cent, and continues to go into solution to some extent up to 0.02 per cent. Its effect on the magnetic properties of all Fe-Si alloys in this range is the same and as far as the hysteresis loss is concerned is expressed by the equation: (W_h = ergs per cu. cm. per cycle for B = 10,000 gauss, and C = carbon content in per cent).

$$W_h = 100{,}000 \times C.$$

2. In amounts greater than 0.007-0.008 per cent, in addition to the amounts in solution, carbon is precipitated in one or more of three forms; depending upon the Si-content (See Fig. 9).

(a) Graphite (in 4-6 per cent Si) with practically no effect.

17. The solid points were obtained by the writer at the University of Illinois in 1915. (See Bull. No. 83, *Eng. Exp. Sta.*)

(b) Fe_3C (in 0 and 4 per cent Si) with the effect: $\Delta W_h = 2250 \times \Delta C$.

(c) Pearlite (in 0 and 2 per cent Si) with the effect $\Delta W_h = 16{,}500 \times \Delta C$.

3. Of the other impurities, sulphur has the most detrimental effect: $W_h = 18{,}000 \times S$ for 0 per cent Si and $W_h = 12{,}000 \times S$ for 4 per cent Si and should be eliminated as far as possible. Mn in small amounts is harmless, and P, while detrimental to a limited amount (0.016 per cent) for 0 per cent Si, is actually beneficial for 4 per cent Si.

4. In addition to the ordinary impurities, it has been found that the magnetic properties depend to a large extent upon the grain structure, in particular upon the intercrystalline amorphous cement. Denoting the number of grains per sq. mm. by N, it has been shown that for low carbon contents (for carbon in solution) the effect of grain size on the hysteresis loss may be expressed approximately by the formula:

$$W_h = 65 \sqrt{N},$$

whereas for precipitated carbon the effect may be expressed more nearly by the formula:

$$W_h = 3\,N.$$

5. The hysteresis loss of any Fe-Si-C alloy, containing the ordinary impurities, S, P and Mn in small amounts, as for instance commercial electrical steels, can be calculated with a good degree of accuracy by means of the relationships given above, using for this purpose the same constants for 0 and 2 per cent silicon and 4-6 per cent silicon.

6. The evidence obtained is to the effect that the increased hysteresis loss, due to carbon and other impurities that are precipitated combined with iron, is caused by the inherent hysteresis loss of these precipitated impurities.

7. As it is found that the hysteresis loss (for carbon in solution) is proportional to the amount of the intercrystalline amorphous material, it is concluded that the latter can be regarded as belonging to the same class as the precipitated impurities, and that the increased hysteresis loss, due to decreased grain size consequently is caused by the inherent hysteresis loss of this amorphous material.

8. Regarding the tremendous effect of carbon in solution, it is suggested that this is due to the entering of carbon, into the more or less stable equilibrium arrangement of the ferro-magnetic structure, and upsetting this equilibrium arrangement.

9. The conclusions reached by means of the hysteresis loss are confirmed by the results obtained for the coercive force, minimum reluctivity and electrical resistance.

10. An attempt has been made in this investigation to separate the various factors influencing the magnetic properties. On account of the large number of factors involved and the large number of separate steps required to obtain the data for the various sets of samples, the conclusion may in some individual case be based on what may seem insufficient evidence. However, if the results are viewed as a whole it will be seen that evidence in one part of the investigation can be used to strengthen evidence in other parts that may seem rather scant if taken by itself. The writer does not wish that the results be considered as final in regard to the various factors affecting the magnetic properties, but it is firmly believed that they are qualitatively correct and that they have opened a new path in the unexplored region of magnetism that may be of service in the further exploration of the same.

ACKNOWLEDGEMENTS

The alloys were prepared partly by Mr. E. F. Long, partly by Mr. A. A. Frey and partly by the writer; the annealing has been attended to largely by Mr. D. C. Mayne; the carbon analysis has been done partly by Mr. A. L. Shields and partly by Mr. D. C. Mayne.

The magnetic testing has been done under the direction of Mr. Thomas Spooner; the chemical analysis, other than the carbon analysis, under the direction of Mr. C. J. Rodman; and the micro-analysis under the direction of Mr. N. B. Pilling.

All of the above work has been done in the Research Laboratory under conditions insuring great accuracy and the results are therefore believed to be as reliable as is possible with the time and money available. The writer feels greatly indebted to all the above colleagues and takes this occasion to express his appreciation for their valuable cooperation.

FARM LIGHTING PLANTS IN GREAT BRITAIN

Individual electric plants are not very widely used on farms in Great Britain, but are found to a considerable extent on large country estates and are becoming increasingly popular for use in small country bungalows. As a rule thay could be arranged to furnish power for pumping or for other industrial purposes, but in practise are rarely so used.

They are probably most popular in Scotland, the American Consul at Glasgow estimating that there are from 6000 to 7000 in the whole of Scotland. They are reported to be extensively used also in the Birmingham district and in the Leeds, Sheffield, and Bradford districts, which would indicate that their use is more general in the Midlands than in other parts of England. It is reported that in the Plymouth district they are quite common on large country estates and farms, from 4000 to 5000 having been sold in the County of Devon. They are not generally used in Ireland, and the few that are in operation are employed for large country homes and hotels.

Estimates from London agencies and dealers indicate that the use of individual lighting plants is steadily increasing. It has been found impossible to obtain figures as to the number of such plants in use.

ILLUMINATION ITEMS

By the Lighting and Illumination Committee

GLARE AND ITS RELATION TO EYE SIGHT CONSERVATION

PROF. F. C. CALDWELL, OHIO STATE UNIVERSITY

The human eye has gone along through countless years, with little change in what was demanded from it. It worked through the daytime, for the most part looking at rather large objects, and when it became dark it generally ceased to function. Now, within just a few years this has all changed. The use of the eye for fine work, for reading and for fine manufacturing operations, has been very greatly increased and then in addition, we are demanding that it do much of its work under artificial light which, furthermore, in many cases is far from good.

The change of lighting facilities has been so sudden that men, trying to use the new illuminants in the same way that they have used the old through countless generations, are likely to produce bad results. Of old, the problem of lighting was little more than the problem of getting the work near enough to the puny flame so that it could be seen, and few and far between were those who did work which needed even so much light. It is not strange, therefore, that many make sorry work of it when they set out unaided and without study to provide themselves with the new light.

The importance of glare has been recognized by regulations against it in the industrial and school lighting codes, drawn up by the Illuminating Engineering Society and followed closely in the laws of several states.

We may note three elements in the production of glare. These are excessive brightness, excessive volume of light flux, and excessive contrast. Though excessive brightness is probably the commonest and most generally recognized source of glare, the other two are also deserving of careful study. The seriousness of glare from too great brightness has enormously increased during recent years on account of the introduction of the tungsten filament lamps, especially the gas-filled type with spiral filament. Even the earlier lamps were too bright to make their use without screening devices desirable, but the consequences of operating the present types in this way are quite intolerable except where the lamps are hung very high. Even where globes or deep reflectors, which hide the lamps, are used, consideration must be given to the quality of the glass. If it is of too low a density, the brightness may still be too great for safety and comfort to the eyes. On the other hand, many kinds of glass which are dense enough to cut down the brightness adequately, absorb too much of the light. The best makes of glass available when used in large enough globes, pass about eighty per cent of the light while still sufficiently reducing the brightness. With the right kind of glass the brightness decreases as the size of globe increases. Thus a 100-watt lamp in a 14-inch globe would give so low a brightness as to be satisfactory for any location, while the same lamp in a 6-inch globe would give a brightness about equal to that of the clear sky and would be at about the limit even when placed well up in the room where it would not constantly come into the field of vision of the occupants. With some types of diffusing glass, the brightness is not uniform, but is greatly increased at a spot in line with the filament. In such cases the above reasoning does not hold and the maximum brightness must be reckoned with.

The second source of glare, that is excessive volume of light flux, is likely to occur wherever powerful light sources, even of comparatively low brightness, are in the field of vision and close to the observer. The influence of amount of flux on glare is also shown in the fact that a large light of a given brightness will be more glaring than a small one of the same brightness. On one occasion the writer experienced a quite uncomfortable case of this type of glare when at a party, the hostess seated the guests at small tables with a birthday cake carrying a number of candles in the center of each table. While the brightness was low and the total light flux was not large, the fact that its source was so near, resulted in a relatively large entrance of flux into the eyes. The familiar cases of glare from a window, opening to the sky and of reflection from snow and water also involve the element of large light flux.

Glare of the third type—that due to excessive contrast—is well illustrated by the difference between the glare from an automobile headlight in the daytime amid bright surroundings, giving little contrast and the same light at night, when surrounded by black darkness, with a maximum of contrast. A window which, placed in a white wall, might cause no discomfort, might become trying if the wall were painted a dark color. Again a luminaire so designed as to light up the ceiling around it may not appear glaring, while another of the same brightness which leaves the ceiling dark may be trying to the eyes.

The three sources of glare have been considered separately, and it is indeed possible to produce glaring conditions where only one of the above causes is present in a notable degree. On the other hand, it is very common to find two or three causes present or even all three in a single instance of glare.

Glare due to reflection from polished surfaces generally comes from below, and its effect is magnified by the greater sensitiveness of the eye to light from this direction. Common cases of this are reflection from bright materials upon which work is being done, glass or polished wood table tops and glossy paper. In the latter case an effect is produced which is known as veiling glare. The bright light reflected from the surface of the paper to the eye largely masks that coming from the type and greatly increases the eye strain involved in reading. Much effort has been made in recent years to encourage the use of paper with a mat surface, especially in school-books, so as to reduce this troublesome phenomenon.—*Extract from Eyesight Conservation Council.*

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

Fortieth Annual Convention

EDGEWATER BEACH, CHICAGO, JUNE 23-27

Present indications point to an enthusiastic and widely attended Annual Convention, June 23 to 27, at Edgewater Beach, Chicago. The technical papers are especially good and will reveal much new information on distribution, cables, automatic stations, reactors, communication, electrical machinery, electrophysics and street lighting.

The great central-station systems and the large industrial plants in and near Chicago will serve to attract many members to the meeting, besides the other sights of Chicago of more general interest. Furthermore, the social and entertainment side of the convention has been expanded, as is the custom for the summer convention of the Institute.

The subjects of the technical papers are given in detail in the accompanying program and, in addition, there are a number of special features.

SPECIAL FEATURES

The President's Address

"Forty Years of the American Institute of Electrical Engineers" will be the subject of President Harris J. Ryan's address on Tuesday morning.

Section Delegates' Meeting

During Monday morning and afternoon the Section delegates will meet under the auspices of the Sections Committee to discuss their problems and means for increasing the usefulness of the Sections. All members are invited to this meeting.

Technical Committee Reports

Following the President's address on Tuesday morning, the reports of the various Technical Committees will be presented. An effort has been made to picture in these reports the major developments which have taken place during the last year and to give an idea of the present status in the various fields of electrical engineering. The reports should give any member an up-to-date knowledge of progress in the different branches of electricity.

The Standards Meeting

The broad viewpoint of the objects and advantages of standardization will be the topic of the address by A. W. Whitney, Chairman of the American Engineering Standards Committee. This address will be given in the meeting on Wednesday evening and will be followed by tentative reports from several of the working committees of the A. I. E. E. Standards Committee. These reports will illustrate concretely the way in which the work of the Standards Committee is being done in order to accomplish the broad advantages of standardization. The reports will be presented mainly for bringing out discussion on certain sections of the proposed revised A. I. E. E. Standards.

TURBINES OF FISK STREET STATION, 230,000 KW. CAPACITY

Educational Committee's Dinner

An informal conference of those interested in education will be held on Tuesday evening. Those attending will meet together at dinner for friendly discussion of educational subjects, no rigid program having been set. Any member who wishes to join this meeting may notify Professor W. C. Bauer, Northwestern University, Evanston, Illinois, or simply state his desire to do so at the registration desk sometime before noon of Tuesday during the convention.

Social Features

On Tuesday evening the President of the Institute will hold a reception and this will be followed by dancing.

An enjoyable entertainment feature called "With the Fairies" will be staged on Thursday evening.

Dancing will be enjoyed every afternoon and evening with music furnished by two of the hotel's excellent orchestras.

Card parties, teas and sightseeing trips are planned especially for the ladies who will be cordially welcomed.

To add to the sociability of the convention, one hour each morning, starting at 9 o'clock, has been set aside as a "Social Hour," during which members may meet in the less formal ways for friendly conversation and discussion.

Inspection and Sightseeing Trips

A number of inspection trips will be made to points of engineering and general interest. In the following paragraphs are listed some of these places.

Calumet Station (Commonwealth Edison Co.)—A boat trip from Lincoln Park will be made to this new station which is now completed.

Waukegan Station (Public Service Company of Northern Illinois)—In this new plant one unit is now in operation. The station has extensive outdoor switching structure and is the terminus of a new 132,000-volt tower line.

Church Street Substation (Public Service Company of Northern Illinois)—This is the other terminus of the 132,000-volt line.

Lakeside Station (Milwaukee Electric Railway & Light Co.)—This is one of the largest stations using powdered fuel.

Central Street Automatic Substation (Chicago Rapid Transit Co.)—This new 2000-kw. automatic substation is equipped with automatic reclosing feeder equipment and a supervisory control system running to the supervisor's office 14 miles away.

Remote-Control Distribution Substation (Commonwealth Edison Co.).

Clifton Ave. Substation, Commonwealth Edison Co.

Machine-Switching Telephone Exchange (Illinois Bell Telephone Company).

Hawthorne Plant of Western Electric Co.

Gary Steel Works.

Pullman Company's Plant.

Points of General Interest—Among the many interesting sights which can be seen are the Fields' Columbian Museum, the Art Institute, the Union Stock Yards and the park and boulevard systems.

Golf, Tennis and Water Sports

The Edgewater Beach Hotel offers many attractions for sports events. Golf courses and tennis courts are close at hand and tournaments will probably be arranged. Bathing in Lake Michigan will be enjoyed and besides there will probably be swimming or diving exhibitions and also boat rides.

Register as Soon as Possible

Registrations should be made as soon as possible in order that arrangements for the meeting can be completed. Those who are planning to attend the convention should notify Mr. M. M. Fowler, General Electric Co., Illinois Merchants Bank Building, Chicago, Ill., of their intention.

Hotel Accommodations

Hotel reservations should be made by communicating directly with the management of the hotel. The Edgewater Beach Hotel, 5300 Sheridan Road, Chicago, Ill., will be the convention headquarters. For the convention there will be a special rate at this hotel of $3.00 per day for single rooms and $3.00 each for those sharing rooms and suites. All of the rooms are outside and have private baths. The plan of the hotel is European, having two excellent restaurants in connection.

Garage Space Should be Reserved

The hotel has garage space available for those who wish to travel to the convention by automobile. Reservations should also be made for garage accommodations.

Reduced Railroad Fares

Arrangements have been made for reduced railroad fares on the "Certificate Plan" for members and dependent members of their families. By this plan the round trip may be made at one and one-half times the cost of a one-way ticket provided at least 250 certificates are turned in at the convention for validation. These certificates are obtainable with tickets costing not less than 67 cents. Every member is urged to secure a certificate in order to help others even though he himself does not make use of it.

The certificate must be requested when purchasing a ticket to the convention. On arrival at the convention it should be handed to the Transportation Committee at the registration desk. This committee will endorse the certificate and pass it to a representative of the railroads for validation. If 250 or more certificates are turned in they will be validated and may later be secured from the Transportation Committee. After validation the certificates entitle the holder to return transportation via the same route at one-half fare. This return rate will obtain up to and including July 1.

The Convention Committee which is arranging the meeting is composed of the following gentlemen: Messrs. R. F. Schuchardt, Chairman, J. E. Kearns, A. W. Berresford, L. A. Ferguson, M. M. Fowler, C. H. Jones, Ernest Lunn, H. A. Lynette, J. C. Martin, T. Milton, L. W. W. Morrow, S. A. Rhodes, D. W. Roper, C. C. Grandy, Geo. E. Wagner, Ellery B. Paine, D. C. Pyke, S. H. Mortensen, E. L. Bailey and H. W. Meyer.

PROGRAM

Note: Complete copies of the technical papers listed in this program may be obtained from Institute Headquarters on request. Most of the papers are now available.

Monday, June 23

10:00 a. m.

Section Delegates and Committee Meetings.

2:30 p. m.

Section Delegates and Committee Meetings

8:00 p. m.

Informal Dance

Tuesday, June 24

9:00 a. m.

Social Hour

10:00 a. m.

President's Address—Forty years of the American Institute of Electrical Engineers, by Harris J. Ryan

Report of Technical Committees

2:00 p. m.

Sports and Entertainment

6:00 p.m.

Educational Committee's Informal Dinner and Conference

8:00 P. M.

President's Reception and Dance

WEDNESDAY, JUNE 25

9:00 A. M.

Social Hour

10:00 A. M.

TWO PARALLEL TECHNICAL SESSIONS

SESSION A, UNDER AUSPICES OF PROTECTIVE DEVICES COMMITTEE, H. R. WOODROW, CHAIRMAN

1. *Automatic Stations for A-C. and D-C. Networks*, by C. W. Place, General Electric Company.
2. *The Cleveland Heights Substation of The Cleveland Electric Illuminating Company*, by H. L. Wallau, The Cleveland Electric Illuminating Co.
3. *Automatic Substation for Supplying 1599 Volts D.-C. to Suburban Railways*, by C. A. Butcher, Westinghouse Elec. & Mfg. Co.
4. *Automatic Motor-Generator Equipments on Edison Service of The Indianapolis Light & Heat Co.*, by Herman Bany, General Electric Co.
5. *Operating Experience with Automatic Equipment on an Edison System*, by F. D. Wyatt, The Union Gas & Electric Co.
6. *Automatically Controlled Hydro-Electric Generating Stations*, by R. J. Wensley, Westinghouse Elec. & Mfg. Co.

SESSION B, UNDER AUSPICES OF TELEGRAPHY AND TELEPHONY COMMITTEE, O. B. BLACKWELL, CHAIRMAN: AND ELECTROPHYSICS COMMITTEE, F. W. PEEK, JR., CHAIRMAN

7. *Selective Circuits and Static Interference*, by J. R. Carson, American Telephone & Telegraph Co.
8. *The Transmission Unit and Telephone Transmission Reference Systems*, by W. H. Martin, American Telephone and Telegraph Co.
9. *Sensitive Radio-Frequency Relay*, by George Lewis, Crosby Manufacturing Co.
10. *The Transient Visualizer*, by H. M. Turner, Yale University.
11. *Temperature Rise of Stationary Electrical Apparatus as Influenced by Radiation, Convection and Altitude*, by V. M. Montsinger and W. H. Cooney, General Electric Co.
12. *Effect of Altitude on Temperature Rise of Electrical Apparatus*, by R. E. Doherty and E. S. Carter, General Electric Co.

2:00 P. M.

Sports and Entertainment

7:30 P. M.

Meeting under Auspices of the Standards Committee, H. S. Osborne, Chairman.

Address, by A. W. Whitney, Chairman, American Engineering Standards Committee.

Standards of the A. I. E. E.—Brief Presentation for Discussion of Certain Sections of the Proposed Revised A. I. E. E. Standards, by the chairmen of the working committees as listed below.

Standards for Transformers, Induction Regulators and Reactors, by John D. Bowles.

Standards for Synchronous Converters, by John C. Parker.

Standards for Industrial Control Apparatus, by H. D. James.

Standards for Electric Arc Welding Apparatus, by F. M. Farmer.

Standards for Insulators, by R. E. Argersinger.

THURSDAY, JUNE 26

9:00 a. m.—Social Hour

10:00 a. m.—Two parallel technical sessions

SESSION A, UNDER AUSPICES OF TRANSMISSION AND DISTRIBUTION COMMITTEE, F. G. BAUM. CHAIRMAN

13. *Underground A-C. Network Distribution*, by A. H. Kehoe, United Electric Light and Power Co.
14. *General Light and Power Supply of Chicago*, by G. M. Armbrust and J. B. Jackson, Commonwealth Edison Co.
15. *Study of Underground Distribution Systems*, by W. R. Bullard, New Orleans Public Service.
16. *Equivalent Single-Phase Networks for Calculating Three-Phase Short-Circuit Currents*, by R. A. Shetzline, American Telephone and Telegraph Co.
17. *Standardization in Construction and Operation*, by M. L. Sindeband, American Gas and Electric Co.

SESSION B, UNDER AUSPICES OF PROTECTIVE DEVICES COMMITTE, H. R. WOODROW CHAIRMAN

18. *Current-Limiting Reactor Characteristics*, by S. I. Oesterreicher, Metropolitan Device Corp.
19. *Design, Installation and Operation of Current-Limiting Reactors*, by H. O. Stephens and F. H. Kierstead, General Electric Company.
20. *Current-Limiting Reactors*, by W. M. Dann, Westinghouse Electric & Mfg. Co.
21. *Theory of the Saturated-Core Regulator and Reactor*, by A. Boyajian, General Electric Company.
22. *Application of the Saturated-Core Regulator and Reactor*, by D. K. Blake, General Electric Company.

2:00 p. m.—Sports and Entertainments

7:30 p. m.—"With the Fairies."

FRIDAY, JUNE 27

9:00 a. m.—Social Hour

10:00 a. m.—Two parallel technical sessions.

SESSION A, UNDER AUSPICES OF ELECTROPHYSICS COMMITTEE, F. W. PEEK, JR., CHAIRMAN; AND LIGHTING AND ILLUMINATION COMMITTEE, G. H. STICKNEY, CHAIRMAN

23. *High-Voltage Cables*, by Wm. A. Del Mar and C. F. Hanson, Habirshaw Electric Cable Co.
24. *The Dielectric Field in an Electric Power Cable*, by R. W. Atkinson, Standard Underground Cable Co.
25. *Direct Method of Calculating Capacitance of Conductors*, by H. B. Dwight, Canadian Westinghouse Co.
26. *Improved Method of Measuring Potential Gradient and Flux Density in Irregular Fields*, by J. F. H. Douglas and E. W. Kane, both of Marquette University.
27. *Some Notes on Street Lighting*, by Preston Millar, Electrical Testing Laboratories.

SESSION B, UNDER AUSPICES OF ELECTRICAL MACHINERY COMMITTEE, H. M. HOBART, CHAIRMAN

28. *Flashing Characteristics of Series and Compound Motors*, by R. E. Ferris, Westinghouse Elec. & Mfg. Co.
29. *The 35,000-kw. Frequency Converter for Hell Gate Station*, by O. E. Shirley, General Electric Co.
30. *The Inertaire Transformer*, by W. M. Dann and D. R. Kellog, Westinghouse Electric & Mfg. Co.
31. *A New Type of Single-Phase Motor*, by S. R. Bergman, General Electric Co.
32. *Theory and Calculation of the Squirrel-Cage Repulsion Motor*, by H. R. West, General Electric Co.

Excursion Trip to the Pasadena Convention

There was never a better time to visit the Great West and see America's incomparable scenic wonders than this Fall when the Pacific Convention of the American Institute of Electrical Engineers will be held in Pasadena. Pasadena is having a fortieth anniversary this year and has prepared herself to entertain whole conventions of visitors during the year. Invitations have been extended by President Harris J. Ryan and by the Convention Committee to the pioneers, past-presidents, and other prominent members who laid the foundation stones and did so much to build up the electrical industry.

Meetings are being arranged at which the pioneers will tell of some of their interesting experiences in the early days and

these should be enjoyed by both the older and the younger members. The younger men especially will be glad of this unusual opportunity to hear these stories in the pioneers' own words.

Plans are being laid to allow these distinguished visitors and others from the Eastern part of the country to travel together to the Pacific Coast in a special train. Stops will be made at interesting points en route and various optional side trips will be arranged for those who care to take them. At the stopping points there will be a choice of several local excursions or complete freedom, as desired.

On the trip to the West the route will be by way of Colorado Springs, Royal Gorge, Salt Lake City, Feather River Canyon, San Francisco, Yosemite and Los Angeles. The return trip may be made by any of a number of routes according to the wishes of each individual, but naturally should include the Grand Canyon of the Colorado.

Special excursion rates will be available and the stops can be made with little additional expense over that for a direct ticket to Pasadena and return. As the excursion tickets are good until October 31, there will be considerable time after the convention closes for making various visits on the return trip.

As an example of the cost of the railroad fare, the round trip fare from New York to Los Angeles, including stopovers and a side trip to the Grand Canyon, will amount to about $147. The minimum round-trip Pullman fare with stop-overs, with New York as a starting point, is about $62. A lower berth from New York is about $16 more. The rates from other points are lower or higher depending on the distance. The accompanying table contains more complete information on the rates. Special Pullman cars for the exclusive use of the party require not less than 25 adult fares and purchase of entire space in Pullman cars at authorized Pullman fares. A special train requires the presentation of not less than 125 adult fares or the equivalent.

A Nationally Important Meeting

The technical papers will be of especial interest and will mark the convention as a national rather than a sectional event. The subjects have been chosen to interest the practical engineer as well as the advanced scientist. Utilization and application, and research are included in the topics to be presented. The technical sessions already planned give an indication of the diversity of subjects. There will be sessions on transmission, distribution and electrical machinery to interest the central station engineers. The application papers will include the use of electricity in irrigation, oil refining, cement mills, lumber working, mining, electrometallurgy, iron and steel and textile mills. There will be a session devoted to telephony and telegraphy, and illumination and other subjects will be covered.

One of the most prominent features will be a lecture by Dr. R. A. Millikan, telling of some of his latest researches in electrophysics and this will be well supplemented by an exceptional group of papers by his colleagues in the Norman Bridge Laboratory of Physics.

The entertainment and sports events which have been planned will give a desired variety to the program and, needless to say of a meeting in California, the trips which will be taken during the convention will be thoroughly enjoyed.

RAILROAD FARES TO SAN FRANCISCO OR LOS ANGELES
SUMMER EXCURSION ROUND-TRIP RATES

(Fares below include side trip to Grand Canyon and return)

From New York City	$147.44
Boston	156.78
Albany	142.32
Schenectady	141.37
Buffalo	125.22
Chicago	95.12
Philadelphia	142.26
Pittsburgh	122.17
Washington	139.57

Tickets will bear final limit to reach original starting point not later than October 31.

Pullman Fares (one way)

Between	Lower	Upper	Compartment	Drawing Room
New York and Chicago	$ 9.00	$ 7.20	$25.50	$31.50
Boston and Chicago	10.13	8.10	28.50	36.00
Albany and Chicago	8.25	6.60	23.25	30.00
Schenectady and Chicago	8.25	6.60	23.25	30.00
Buffalo and Chicago	5.63	4.50	15.75	21.00
Philadelphia and Chicago	8.25	6.60	23.25	30.00
Pittsburgh and Chicago	4.50	3.60	12.75	16.50
Washington and Chicago	8.25	6.60	23.25	30.00
Chicago and San Francisco (direct)	23.63	18.90	66.75	84.00
Chicago and Colorado Springs	10.88	8.70	30.75	39.00
Colorado Springs and Salt Lake City	7.50	6.00	21.00	27.00
Salt Lake City and San Francisco	9.00	7.20	25.50	31.50
San Francisco and Los Angeles	4.50	3.60	12.75	16.50
San Francisco and Merced	3.00	2.40	9.00	10.50
Merced and Los Angeles	3.75	3.00	10.50	13.50
Los Angeles and Chicago via Grand Canyon (one day)	28.13	22.50	78.75	99.00

Northeastern District Regional Meeting

The dates of the Northeastern District Meeting which is to be held in Worcester, Mass., have been changed to June 4 and 5. The announcement published in the May Journal gave June 5 and 6 as the dates but these were changed because the commencement exercises of Worcester Polytechnic Institute will be held on June 6. It was thought that some of the members would like to attend these exercises.

Also a few changes have been made in the program since the publication of the previous announcement. The announcement which has been mailed to members gives the revised program.

Annual Business Meeting and New York Section Meeting

NEW YORK, MAY 16, 1924

The Annual Business Meeting of the Institute was held at 8.30 p. m. on the evening of Friday, May 16, 1924 in the Auditorium of the Engineering Societies Building, New York. The business meeting, which was held jointly with a New York Section meeting, was opened by Chairman Morehouse of the New York Section who turned the meeting over to President Ryan. The President called upon Secretary Hutchinson to present the Annual Report of the Board of Directors. The Secretary presented this report in abstract, calling particular attention to the growth of the Institute during the past year as instanced in the report of the Membership Committee and in the summary of Section and Branch activities.

The report of the Committee of Tellers on the election of officers of the Institute was then presented by the Secretary; and in accordance therewith, President Ryan declared the election of the following officers, whose terms will begin August 1, 1924:

President:	Farley Osgood, Newark, N. J.
Vice-Presidents:	
District No. 1	Harold B. Smith, Worcester, Mass.
District No. 3	L. F. Morehouse, New York
District No. 5	Edward Bennett, Madison, Wis.
District No. 7	H. W. Eales, St. Louis, Mo.
District No. 9	John Harisberger, Seattle, Wash.
Managers:	John B. Whitehead, Baltimore, Md.
	E. B. Merriam. Schenectady, N. Y.
	J. M. Bryant, Austin, Tex.
Treasurer:	George A. Hamilton, Elizabeth, N. J.

These officers together with the following hold-over officers, will constitute the Board of Directors for the next administrative

year, beginning August 1: Harris J. Ryan, Stanford University, Calif.; Frank B. Jewett, New York; J. E. Macdonald, Los Angeles, Calif; Herbert S. Sands, Denver, Colo.; S. E. M. Henderson, Toronto, Ont.; H. E. Bussey, Atlanta, Ga.; William F. James, Philadelphia, Pa.; R. B. Williamson, Milwaukee, Wis.; A. G. Pierce, Pittsburgh, Pa.; Harlan A. Pratt, Hoboken, N. J.; H. M. Hobart, Schenectady, N. Y.; Ernest Lunn, Chicago, Ill.; G. L. Knight, Brooklyn, N. Y.; W. M. McConahey, Pittsburgh, Pa.; W. K. Vanderpoel, Newark, N. J.; H. P. Charlesworth, New York

President Ryan then called upon President-Elect Farley Osgood to say a few words. Mr. Osgood expressed his realization of the honor conferred upon him by the membership and pledged himself to the full to carry out the established policies of the Institute. President Ryan then turned the meeting back to Chairman Morehouse, who called upon the President to give his talk to the Section on "The Atmosphere as a Factor in Electrical Engineering." President Ryan's talk, which it is expected to publish later, dwelt particularly upon his researches in corona phenomena in connection with high-tension transmission. He began by pointing out the conditions governing the generation, transmission and consumption of power in the entire Pacific Coast region, emphasizing the certainty of increasing length of transmission which will be necessitated by the spread of population and industry. He then proceeded to outline the factors affecting corona on cables, particularly on 60-cycle transmission. His entire talk was profusely illustrated with lantern slides giving the data obtained in his work. At the close of Professor Ryan's talk Mr. F. W. Peek, Jr. of the G. E. Co. discussed some of the principal points and called attention to interesting facts developed in connection with the experiments made at Pittsfield in the simulation of lightning phenomena. Chairman Morehouse then closed the meeting with a vote of thanks on behalf of the N. Y. Section.

Report of Committee of Tellers on Election of Officers

To the President,

American Institute of Electrical Engineers

Dear Sir:

This committee has carefully canvassed the ballots cast for officers for the year 1924-1925. The result is as follows:

Total number of ballot envelopes received		8403
Rejected on account of bearing no identifying name on outer envelope, according to Art. VI, Sec. 34, of the Constitution	129	
Rejected on account of voter being in arrears for dues on May 1, 1924, as provided in the Constitution and By-laws	194	
Rejected on account of ballot not being enclosed in inner envelope, or being improperly marked, or on account of inner envelope or ballot bearing an identifying name, according to Art. VI, Sec. 34, of the Constitution	470	
Rejected as duplicate ballots	5	
Rejected on account of having reached the Secretary's office after May 1, according to Art. VI, Sec. 34, of the Constitution	65	
	863	863
Leaving as valid ballots		7540

These 7540 valid ballots were counted, and the result is shown as follows:

For President

Farley Osgood	3899
Charles E. Skinner	3628
Blank	13

For Vice-Presidents

District		
No. 1 *North Eastern*		
	Harold B. Smith	6687
	Blank	853
No. 3 *New York City*		
	L. F. Morehouse	6480
	*Philip Torchio	600
	Blank	460
No. 5 *Great Lakes*		
	Edward Bennett	5773
	Chester I. Hall	1276
	Blank	491
No. 7 *South West*		
	H. W. Eales	5902
	George C. Shaad	1117
	Blank	521
No. 9 *North West*		
	John Harisberger	7061
	Blank	479

For Managers

John B. Whitehead	6651
E. B. Merriam	6201
J. M. Bryant	5562
Edward L. Moreland	1329
Ross B. Mateer	1157
*H. A. Kidder	440
*Julian C. Smith	286
Blank	994

For Treasurer

George A. Hamilton	6514
Blank	1026

Respectfully submitted,

J. B. Bassett, *Chairman* — Irving W. Green
James F. Kelly — B. Tikhonovitch
R. R. Kime — *Committee of Tellers.*

Date May 13, 1924.

*Withdrew prior to distribution of ballots.

World Power Conference

On June 19th when the S. S. Scythia sails from New York there will be on board a large number of engineers representing many branches of the profession, all en route to the World Power Conference to be held in London June 30 to July 12. The classified program for the Conference has now been issued. Thirty-seven papers are to be presented under the auspices of the American Committee, covering the general range of topics to be discussed. The program is arranged in five principal divisions, as follows:

I—*Power Resources:*—A National Review of Power Resources; II *Power Production*—Water-Power Production—Preparation of Fuels—Steam-Power Production—Internal Combustion Engines—Power from Other Sources; III—*Power Transmission and Distribution:* IV—*Utilization of Power*—Power in Industry and Domestic Use—Power in Electro-Chemistry and Electro-metallurgy—Power for Transport—Power for Illumination; V—*General*—Economic, Financial and Legal—Research, Standardization, Education, Health, Publicity.

The Conference will open with the Official Reception and Address by the President at 3.30 p. m. on June 30th. In the evening the formal banquet to the delegates will be held. On Thursday, July 10th the Institution of Electrical Engineers will give a luncheon. At 4.30 the presentation of the Kelvin Medal to Prof. Elihu Thomson will take place, followed by addresses by delegates and Memorial Oration by Sir. J. J. Thomson. At 6.45 p. m. on the 11th the Kelvin Centenary Banquet will be held with Lord Balfour in the chair. On the remaining days there will be numerous special trips to places of engineering and historic interest.

Farley Osgood

PRESIDENT ELECT OF THE A. I. E. E.

Farley Osgood, Vice-President and General Manager of the Public Service Electric Company, Newark, N. J. has been elected President of the American Institute of Electrical Engineers for the year beginning August 1, 1924, as announced in the report of the Committee of Tellers published elsewhere in this issue.

He was born in Chelsea, Mass. in 1874 and was educated at the Massachusetts Institute of Technology. Mr. Osgood's first work, 1894, was in the Engineering Dept. of the American Bell Telephone Co. in Boston, where he remained three years. During the year 1897-98 he was traveling engineer for the New England Telephone & Telegraph Co. making inspections and installations. In 1898 he went with the New York and New Jersey Telephone Co. as chief clerk in the Operating Dept., special plant engineer, and finally Division Manager. In 1904 Mr. Osgood became Chief Engineer and General Manager of the New Milford Power Co., Conn. He finished the construction work of this company, being responsible for greatly developing its system, then organized the operating force and ran the company. In 1908 he returned to New Jersey and became associated with the Public Service Electric Co., of New Jersey as General Superintendent. He then became Asst. General Manager and finally Vice President and General Manager, the position which he holds today.

Mr. Osgood is a Fellow of the A. I. E. E., having entered as Associate in 1905. He served as Manager during 1911-12-13 and 1914 and as Vice-President of the Institute in 1914-15-16. He was Chairman of the New York Section in 1921-22 and has been a member of the following committees: Executive, Finance, Edison Medal, Standards and Safety Codes.

FARLEY OSGOOD
PRESIDENT-ELECT OF THE A. I. E. E.

A. I. E. E. Directors, Meeting

The regular bi-monthly meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Friday, May 16, 1924.

There were present: President Harris J. Ryan, Stanford University, Cal. Vice-Presidents W. I. Slichter, New York, G. Faccioli, Pittsfield, Mass.; S. E. M. Henderson, Toronto, William F. James, Philadelphia; Managers Harold B. Smith, Worcester, Mass., E. B. Craft, H. P. Charlesworth, New York, H. M. Hobart, Schenectady, G. L. Knight, Brooklyn, N. Y., A. G. Pierce, Pittsburgh, Harlan A. Pratt, Hoboken, N. J., W. K. Vanderpoel, Newark, N. J.; Treasurer George A. Hamilton, Elizabeth, N. J., and Secretary F. L. Hutchinson, New York.

The minutes of the Directors' meeting of March 14, 1924, were approved as previously circulated.

Reports were presented of meetings of the Board of Examiners held April 7 and May 12; and the actions taken at those meetings were approved. Upon the recommendation of the Board of Examiners, the following action was taken upon pending applications; 93 Students were ordered enrolled; 127 applicants were elected to the grade of Associate; 4 applicants were elected to the grade of Member; 9 applicants were transferred to the grade of Member; 2 applicants were transferred to the grade of Fellow.

The annual report of the Board of Directors for the fiscal year ending April 30, 1924, as prepared by the Secretary, was presented and accepted as printed, for presentation at the Annual Business Meeting during the evening of the same day. The annual report of the Treasurer, for the fiscal year ending April 30, 1924, was presented, accepted, and ordered filed. The annual reports of various standing committees (exclusive of technical committees), abstracts of which had been incorporated in the Board of Directors' report, were presented, received, and ordered filed for reference, particularly by the chairmen of the incoming committees of the next administration.

In accordance with Section 37 of the constitution, the appointment of a Secretary for the administrative year commencing August 1, 1924, was considered; and Secretary F. L. Hutchinson was reappointed.

Upon request of the Standards Committee it was voted that the Plan of Organization of the Standards Committee be amended so as to include the President of the U. S. National Committee of the International Electrotechnical Commission as an ex-officio member of the Standards Committee.

Standards on Industrial Control Apparatus were submitted by the Standards Committee for approval by the Board; and it was voted that these Standards be adopted and published as Institute Standards. (These will constitute the first separate section of the revised Institute Standards to be issued.)

The resignation was presented of Mr. Gano Dunn as a representative of the Institute upon the Board of Management of the World's Congress of Engineers to be held in Philadelphia, in 1926; and upon the nomination of President Ryan Mr. Paul M. Lincoln was appointed to succeed Mr. Dunn on the Board of Management of the World's Congress of Engineers.

An invitation to appoint a representative to participate in

the Centenary celebration of the Franklin Institute, in Philadelphia, September 17-19, 1924, was referred to the President with power.

An invitation to send delegates to the International Mathematical Congress to be held at Toronto, August 11-16, 1924, was referred to the President with power.

It was voted that an invitation be extended to the newly elected officers of the Institute to attend the meeting of the Board of Directors to be held during the Annual Convention, in June.

Reference to other matters discussed may be found in this and future issues of the JOURNAL under suitable headings.

Board of Directors' Report

FOR THE YEAR ENDING APRIL 30, 1924

The Annual Report of the Board of Directors of the A. I. E. E. was presented at the Annual Business Meeting of the Institute held in New York, Friday evening, May 16, 1924.

This report consists of a brief summary of the principal activities of the Institute during the year, including abstracts of various reports submitted by officers and committees, covering their respective branches of work. The more important matters referred to in the report have been, or will be, covered in much more detailed form in the JOURNAL, and therefore the report will not be published in full herein, but any member of the Institute may obtain a pamphlet copy upon application to the Secretary of the Institute.

The growth in Institute membership during the year is indicated in the following tabulation:

	Honorary Member	Fellow	Member	Associate	Total
Membership, April 30, 1923	6	578	2,264	12,450	15,298
Additions:					
Transferred		20	79		
New Members Qualified		4	96	2,040	
Reinstated		4	9	53	
Deductions:					
Died		6	11	51	
Resigned		5	15	222	
Transferred			14	85	
Dropped		1	49	689	
Membership, April 30, 1924	6	594	2,359	13,496	16,455

Net increase in Membership during the year....1,157

The activity of the Sections and Branches during the year and the growth in the number of these organizations, also in the number of meetings held by them and in the aggregate attendance, are shown in the following statement:

	For Fiscal Year Ending						
	May 1 1918	May 1 1919	May 1 1920	May 1 1921	May 1 1922	May 1 1923	May 1 1924
SECTION							
Number of Sections	34	34	36	42	45	46	47
Number of Section meetings held	245	217	262	303	373	344	381
Total Attendance	34,614	25,837	30,741	37,823	54,378	46,672	58,945
BRANCHES							
Number of Branches	59	61	62	65	67	68	77
Number of Branch meetings held	268	156	360	443	439	503	530
Attendance	10,683	6,441	16,827	21,629	25,358	26,893	25,674

The Finance Committee's Report, together with the general balance sheet and detailed financial statements of the Certified Public Accountants who audited the Institute books, is included in the report.

Lightning-Arrester Performance

BASIS OF COMPARISON, RECOMMENDED BY LIGHTNING ARRESTER SUB-COMMITTEE OF THE PROTECTIVE DEVICES COMMITTEE

In studying the performance of lightning arresters it is convenient to start with the hypothetical curve of the potential wave traveling along a circuit wire, as the result of a lightning discharge or other abnormal disturbance. Up to the present time it has not been found possible to determine the actual form of the potential curve of such a traveling wave, but it is felt that a representative analysis may be made by considering the general wave forms shown in Fig. 1, in which for simplicity the normal line voltage is omitted.

In most cases the important portion of the traveling wave is the first impulse, regardless of whether or not the phenomenon is

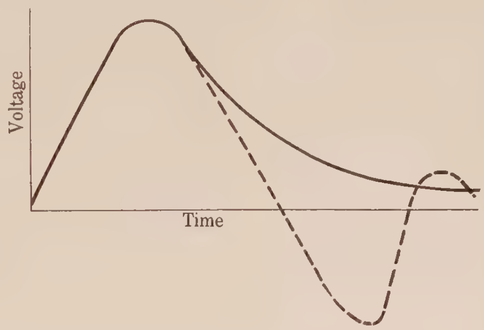

FIG. 1—VOLTAGE-TIME CURVE OF TYPICAL TRAVELING POTENTIAL WAVE, CAUSED BY LIGHTNING DISCHARGE

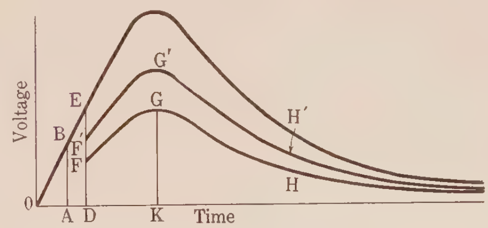

FIG. 2—VOLTAGE-TIME CURVES SHOWING EFFECT OF LIGHTNING ARRESTERS

oscillatory. There are attendent conditions during the lightning stroke that lead some of us to conclude that the duration of the first impulse of some waves is of the order of time of only a few micro-seconds. With this assumption as a basis, the object is to analyze what happens in the first one hundred-thousandth of a second following the arrival of the wave.

If the lightning arrester is of the spark-gap type, or is of the type which consists of a single spark gap in series with other portions of the arrester, (and this includes most of the types now on the market) then a certain potential is required to discharge across the spark gap. This potential is indicated by $A\ B$ in Fig. 2, in which $O\ A$ represents the time required for the potential to reach this value. The arrester, however, does not begin to discharge at the instant that this potential is reached. There is a well-known property of all insulating materials which requires the application of the potential for a certain brief time, called the dielectric spark lag, before the discharge begins. This lag in time is indicated by $A\ D$. In the meantime, the potential has increased to a value $D\ E$. The potential has now reached the point E on our curve after a total interval of $O\ D$, and the

point E, therefore, represents the point on the curve corresponding to the time at which the initial discharge takes place across the arrester. $D\ E$ therefore represents the potential across the arrester immediately before the instant of discharge, but following the beginning of the discharge the current flows through the arrester, and the potential across the arrester is dependent upon the instantaneous current and value of the resistance and inductance of the arrester, and upon the drop in voltage across any series gaps.

The potential across the arrester falls after the discharge begins to some such value as $D\ F$. From this time the potential across the arrester will follow a curve $F\ G\ H$, the ordinates of which are dependent upon the instantaneous current and value of the resistance and inductance of the arrester, and upon the drop in voltage across any series gaps.

The Curve $B\ E\ F\ G\ H$ is a criterion of the performance of the arrestors. The voltage of the equivalent sphere gap will be either $D\ E$ or $K\ G$, depending on which is the greater. From this curve it can be seen that the several ways in which the maximum voltage across the terminals of a lightning arrester can be reduced are:

1. By reducing the spark gap voltage ($A\ B$).
2. By reducing the dielectric spark lag ($A\ D$).
3. By reducing the resistance and the inductance of the arrester (which determines $K\ G$).

The values of $A\ B$, $D\ E$, and $K\ G$ should be as low as possible. There is a practical limit below which the value $A\ B$ cannot be reduced. This depends upon the type of arrester considered and the extreme voltage regulation of the circuit. This low limit for $A\ B$ is determined by laboratory tests and operating experience in the field, and by the line voltage.

The dielectric spark lag $A\ D$ is difficult to measure and indirect methods have been resorted to. Studies of F. W. Peek, Jr. have shown that sphere gaps are faster than any other form of gap. As a result, most types of lightning arresters, since the publication of Peek's data, have used as sphere gaps electrodes approximating the shape of a sphere.

In the case of the aluminum cell on d-c. circuits, the arrester can be connected directly to the circuit without any intervening gap, and this eliminates the dielectric spark lag. In this case the discharge will start to flow into the arrester with the first increase in voltage above the line voltage because of the high capacitance of the aluminum cell. Passage of heavy current by the valve action of the film will take place only if the voltage $K\ G$ exceeds the valve voltage of the cells.

Up to the present time no alternating-current arresters have been produced for commercial service which operate without a spark gap in series. Several types of arresters, however, operating on the valve principle, behave similar to a counter e. m. f. and permit a gap setting materially lower than other types of arresters. This means that these arresters can be operated with a setting having a smaller margin above the normal operating voltage than arresters which consist of a series of spark gaps and resistors in combination.

Referring again to Fig. 2, if the resistance is increased, then the voltage curve during discharge will be similar to $F'\ G'\ H'$. That is, the higher the resistance of the arrester, the higher will be the maximum voltage during the discharge.

The interesting question in connection with the efficiency of a lightning arrester is not to determine merely that it will show signs of a discharge at the time of a lightning stroke, as might be shown by the puncture of a paper in a series gap, but how much of the current induced by the lightning discharge will the arrester allow to flow to ground.

Arresters with valve characteristics which cut off current flow for voltage at or near normal line voltage may safely be of low resistance, permitting a high discharge rate for transient excess voltage. Laboratory tests made with "lightning generators" confirm the results of tests on arresters in service, in showing that, other things being equal, the type of arrester having the lowest resistance and inductance is the most efficient protective device. In this connection, the importance of good grounds and short, direct leads cannot be too greatly emphasized, as lack of care in these respects may easily introduce sufficient resistance and inductance into the discharge circuit to nullify the effect of an otherwise efficient lightning arrester.

The above statements must not be taken as indicating the only qualifications that a satisfactory arrester must have. An arrester that has only a low resistance to steep wave-front impulses is not necessarily an acceptable arrester. For example, a horn gap connected directly to ground without limiting resistance has a minimum of resistance and a maximum of ability to cause trouble. Other factors have to be considered, such as those which have a bearing on non-interruption of service and on the ability of the arrester to withstand self-destruction.

For alternating-current service the ideal type of arrester would be one that would have characteristics corresponding closely to those of the aluminum cell arrester in direct-current service. That is, one which could be connected directly to the circuit, and so adjusted that under normal operating conditions, only a negligible current would pass through the arrester, but which would have, in addition, the property that above a certain critical voltage a very high current would flow through the arrester as soon as the voltage across the arrester exceeded the critical value.

Purchaser's Tentative Specifications for Current-Limiting Reactors

The Sub-committee on Current-Limiting Reactors of the Protective Devices Committee of the A. I. E. E. has felt the need of a Purchaser's Specification for Current-Limiting Reactors. This matter has been considered during the last two years, and as a result, a Tentative Purchaser's Specification has been prepared.

The Sub-committee desires that if any of the readers of the Journal of the A. I. E. E. has any suggestions or criticisms to make, he will forward them to the Chairman of the Sub-committee, N. L. Pollard.

I. Type

The reactors herein specified shall be of the single-phase, air-core, self-cooled type and are to be used for (indoor) (outdoor) service.

II. Rating

These reactors shall be designed to produce a reactive drop of .... per cent when connected in a .... -volt, ... -phase, ... -cycle circuit carrying a current of .... amperes.

The maximum deviation of the reactive drop should not exceed 5 per cent plus or minus from the specified value. The average value of the reactive drop shall not differ from that specified by more than 2 ½ per cent.

III. Short Circuit Characteristics

Each single-phase reactor or set of reactors starting at normal operating temperature shall be capable, when arranged as in paragraph 9, of withstanding without thermal or mechanical injury for a period of .... seconds, the maximum current which would result from any short circuit with normal line voltage maintained at the supply terminals and with only the inherent reactance of the reactor in the circuit. The manufacturer shall supply braces if necessary for the proposed installation.

IV. Temperature Rise

After continuous operation (under proper ventilating conditions to be defined by the manufacturer under IX) and at normal rated current and frequency, until the temperature of the reactor becomes constant, the temperature rise of any part of the

reactor above the ambient air shall not exceed the value specified in the manufacturer's specifications. The maximum temperature, with ambient air at 40 deg. cent. shall not exceed the temperature limits prescribed by the Standards of the A. I. E. E. for the class of insulating material used.

V. TEMPERATURE MEASUREMENTS

The final maximum temperature of the reactor shall be obtained by the thermometer and by the rise in resistance methods. The highest temperature obtained by either of these methods shall be taken as the final temperature of the reactor. The method of calculating the final temperature from the increase in resistance shall be in conformity with the Standards of the A. I. E. E. No "hot spot" correction shall be made to the maximum observed or calculated temperature. The temperature rise shall be the difference between the maximum temperature obtained and the average temperature of the surrounding air at the close of the test.

VI. LOSSES

The losses stated in the manufacturer's specifications shall be the total losses at rated current and frequency at 75 deg. cent. temperature.

As a guide to the manufacturer, the purchaser considers it economical to pay .... dollars more for each reactor for each kilowatt reduction in loss therein.

VII. TESTS

Tests above specified for temperature rise and losses shall be made on .... reactors of each design.

The following tests shall be made on all reactors:

1. High-potential tests between winding and ground at normal frequency and .... volts for one minute.
2. High-potential, high-frequency test across the reactor terminals at .... volts for one minute.
3. Tests to determine the impedance of the reactor at normal rated current and frequency at normal room temperature.
4. Test to determine the direct-current resistance of the reactor at normal room temperature.

In no case shall this resistance exceed by more than 5 per cent the average resistance of all the reactors covered by these specifications.

The manufacturer shall supply the purchaser with copies of all test records.

VIII. MEANS FOR LIFTING REACTOR

Suitable means for lifting each reactor shall be provided.

IX. INSTALLATION

The purchaser desires to install each .... -phase group of reactors herein specified in a space approximately .... inches long, ... inches wide, and .... inches high.

Magnetic materials adjacent to this space are as follows:

It (is / is not) the purchaser's desire to install each reactor in a separate compartment.

The purchaser's suggestion as to the arrangement of the reactors in the available space is as follows, or as shown on the accompanying sketch.

X. DATA REQUIRED FROM MANUFACTURERS

The manufacturer shall supply the purchaser with the following information relative to the herein specified reactors:

1. No. of phases.
2. Kv-a. rating of reactors.
3. Full-load current in amperes.
4. Line voltage.
5. Reactive drop in volts across reactor.
6. Root-mean-square short-circuit current for which reactors are designed.
7. Maximum current through reactors for five seconds without injury to reactors.
8. Temperature rise at full-load current.
9. Total losses in kw. at 75 deg. cent. temperature.
10. Size of conductor in cir. mils and number of circuits in parallel.
11. Weight of reactor.
12. Dimensions of reactor.
13. Outline drawing showing supporting or bracing insulators, clamps and other recommended equipment necessary for the reactor installation.
14. The minimum area of the opening required at the top and bottom of the reactor should not be less than ...... sq. feet per kw. loss for cooling air with natural ventilation.
15. Recommended distances from magnetic material.

NOTE: Should the manufacturer find it impracticable to design single-phase reactors for the available space as herein specified, he may offer a design of polyphase reactor to conform in general to the specified requirements.

Death of T. Commerford Martin

T. COMMERFORD MARTIN, President of the Institute 1887-88, died suddenly on Saturday, May 17, 1924. Mr. Martin was recuperating from a serious operation at his summer home in Massachusetts when taken ill. He was born in London in 1856. He entered the Countess of Huntington College as a theological student. In 1877 he came to America and took up work in the laboratory of Thos. Edison, chiefly on phonographs, telephones, etc. In 1879 he went to Jamaica, West Indies where he edited a paper until 1882. He then returned to the U. S. and edited the "*Operator*" and in 1883 got out the first issue of the "*Electrical World*" and he continued as editor of that Journal and its components until 1909, when he became Executive Secretary of the National Electric Light Association. Mr. Martin who was a founder and charter member, has held every office in this Institute except that of Treasurer and it was only in our last issue, May, that an appreciation of his life and work as one of the the leaders of the A. I. E. E. was published.

Joseph Henry in the Hall of Fame

At New York University on the afternoon of Tuesday, May 13, 1924, Thomas A. Edison unveiled in the Hall of Fame, the bust of Joseph Henry, educator and scientist. The bust was presented to the University by the A. I. E. E. and provided from funds raised by member subscription and by appropriation. The bust is one of ten just added to the many already in place above commemorative tablets to famous Americans. Frank B. Jewett, former president of the Institute, made the commemorative address. Dr. Jewett called attention to Henry's independent discovery of electromagnetic induction, his hypothesis concerning the oscillatory nature of electric discharge and his part in the manufacture of insulated wire. The speaker also pointed out the part he played in the building up of the Smithsonian Institution and of the National Academy of Sciences.

In conclusion Dr. Jewett said, "Henry was perhaps the foremost American physicist. And it is well attested by every record that he was a man of varied culture, of large breadth and liberality of views, of generous impulses, of great gentleness, of courtesy of manner combined with equal firmness of purpose and energy of action. He was, in every way and in the best that the word denotes, a scientist, ..."

Omaha to Hold Electrical Exposition

An electrical exposition is being planned by the city of Omaha for the early part of November. It is to be a memorial to the late C. P. Steinmetz and a celebration of 40 years of electrical achievement in America. Many of the largest electrical companies of the world will have exhibits, for which prizes will be given. One of the largest exhibits will be devoted to radio.

With the cooperation of the electrical jobbers and dealers throughout the country, Omaha expects this to be one of the largest and most successful exhibitions to be held in that part of the country.

Dr. De Forest Talks to 2000 at Yale Branch Meeting

A most interesting lecture given by Dr. Lee De Forest before the Yale University Branch on May 7 was enjoyed by an audience of 2000 people. Dr. DeForest spoke of the various methods which have been employed to obtain "talking motion pictures" and described in detail the various steps in the operation of the method which he has developed. He also outlined the practical possibility of his development, the "Phonofilm." Demonstrations of various features of the method were made during the course of the lecture by means of several reels of the film.

Hayden and Steinmetz Paper Wins Transmission Prize

The Report of the Committee on Award of Institute Prizes was approved by the Board of Directors on May 16. This report which states the decision of the committee on the award of prizes for the year 1923 is given below.

REPORT OF THE COMMITTEE ON AWARD OF INSTITUTE PRIZES FOR THE YEAR 1923

THE TRANSMISSION PRIZE

The Committee has chosen the following paper to receive the Transmission Prize:

"High-Voltage Insulation," by J. L. R. Hayden and Charles P. Steinmetz.

HONORABLE MENTION

(1) "A New Method for Routine Testing of Alternating-Current High-Voltage Paper-Insulated Cable," by Howard S. Phelps and E. Dean Tanger.

(2) "Artificial Transmission Lines with Distributed Constants," by F. S. Dellenbaugh, Jr.

THE FIRST PAPER PRIZE

No eligible paper was entered in competition for this prize and consequently no award is to be made.

COMMITTEE ON AWARD OF INSTITUTE PRIZES

L. W. W. MORROW, Chairman
F. G. BAUM
DONALD MCNICOL

Westinghouse Company's Fortieth Anniversary

Just 40 years ago, George Westinghouse started his career in the field of electricity. On May 20, 1884 he signed a contract with William Stanley, whose great gift to the industry while connected with Westinghouse was the development of the transformer, which has made possible the long distance transmission of alternating current at relatively high voltages, reducing it to low, usable voltages at the necessary points. Before this time direct current only was used.

Many of the greatest achievements in the world of electricity have been the result of experiments made by the Westinghouse company, among which are: a commercial a-c. system, the transformer, the Shallenberger meter, the Wurtz lightning arrester, Stillwell regulator, Tesla motor and Mershon compensator.

This company has also been connected with the lighting of the Chicago World's Fair, the utilizing of power of Niagara Falls, the introduction of the steam turbine in America, and the electrification of various railroads both here and abroad

With such a notable list of accomplishments, in the comparatively short time since electricity began to be a factor in commerce, the future promises amazing progress, in which the Westinghouse Company will undoubtedly continue to play a prominent part.

ENGINEERING FOUNDATION

ROOM ASSIGNED IN NATIONAL ACADEMY OF SCIENCE AND NATIONAL RESEARCH COUNCIL BUILDING

The new building for the National Academy of Science and the National Research Council was dedicated with fitting ceremony on April 28th, in Washington, D. C. In token of the appreciation of the assistance rendered, a room was formally assigned to the Engineering Foundation.

President A. A. Michelson of the National Academy and Past President Gano Dunn, as Chairman of the Council and Building Committee took part in the presentation and Vice Chairman Edward Dean Adams accepted for the Foundation. Dr. Ambrose Swasey, the founder of the Engineering Foundation, expressed the gratification that was felt as the result of the cooperation between scientists and engineers.

Montefiore Prize for Contributions on Electrical Developments

A triennial prize of almost 15,000 francs for the best original paper presented on scientific progress and development in any branch of electricity has been established by the George Montefiore Foundation, Liege, Belgium. This prize was instituted by George Montefiore, late President of Honor of the Association des Ingenieurs Electriciens and founder of the Institut Electrotechnique Montefiore.

The competition for the 1923-25 award is now open and all works submitted for this prize should be received by the Foundation by April 30, 1925. The amount of the prize for this term is approximately 22,500 francs, which is somewhat greater than the normal amount.

Detailed information may be secured from M. le Secretaire-Archiviste de la Foundation George Montefiore, Association des Ingenieurs Electriciens, rue Saint-Gilles, 31, Liege, Belgium.

Addresses Wanted

A list of names of members whose mail has been returned by the Postal authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York, N. Y.

All members are urged to notify the Institute headquarters promptly of any change in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

1.—J. T. Brown, 522-32nd St., Oakland, Calif.
2.—John P. Byron, c/o Waldorf Hotel, Seattle, Wash.
3.—B. L. Cathey, 736 Ross Ave., Wilkinsburg, Pa.
4.—D. S. Dewire, 39-6th Ave., La Grange, Ill.
5.—W. A. Harding, Camp 60, Big Creek, Calif.
6.—J. A. Hooper, 195 E. 47th St., Portland. Ore.
7.—Tadashi Iida, Architectural Dept., So. Manchuria Rwy. Co., Dairen, Manchuria.
8.—Herbert A. Kellar, Colorado Power Co., Glenwood Springs, Colo.
9.—Charles L. Kern, 1515 Monroe St., Chicago, Ill.
10.—Albert L. Luther, 9341 Moffat St., Detroit, Mich.
11.—Orrin MacMurray, c/o Crocker-Wheeler Co., Ampere, N.J.
12.—S. F. Nelson, 57 ½ So. Pryor St., Atlanta, Ga.
13.—Thos. W. Rule, 500 Central National Bank Bldg., Topeka, Kans.
14.—R. L. A. Strathy, 369 Clarke Ave., Apt. 5, Westmount, Que., Can.
15.—W. J. Timmins, 1219-11th St., Des Moines, Iowa.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

BOOK NOTICES (APRIL 1-30, 1924)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

ALTERNATING CURRENTS.

By Alfred Hay. 5th edition, rev. & enl. Lond., & N. Y., Harper & Bros., 1923. 420 pp., diagrs., 9 x 6 in., cloth. $3.50.

Intended to furnish a general account of the principles, construction and use of alternate-current measuring instruments, generators, motors and transformers. Gives special attention to methods of testing. This edition contains new matter on polyphase commutator motors, the theory of unbalanced polyphase systems, instrument transformers and phase converters.

L'ANALYSIS SITUS ET LA GEOMETRIE ALGEBRIQUE.

By S. Lefochetz. Paris, Gauthier-Villars et Cie., 1924. 154 pp., 10 x 6 in., paper. 20 fr.

This monograph on Analysis Situs forms one of a series on the theory of functions issued under the editorship of Emile Borel, of the Institut de France. It is partially based on a series of lectures given in Rome, in 1921, under the auspices of the Institute of International Education, and on investigations carried out, shortly before that time, under the auspices of the American Association for the Advancement of Science.

APPAREILS ET INSTALLATIONS TELEPHONIQUES.

By E. Reynaud-Bonin. Paris, J. B. Baillière et Fils, 1924. 487 pp., illus., diagrs., tables, 9 x 6 in., paper. 50 fr.

Beginning with the subscribers' apparatus, the author successively considers the manual exchange, telephone networks, special installations, automatic telephony and the theory of telephone apparatus and lines. The work is descriptive rather than theoretical and is intended as a general introduction to the subject.

DRANG UND ZWANG ....vol. 1

By Aug. Föppl and Ludwig Föppl. 2d edition. Münich u. Berlin, R. Oldenbourg, 1924. 359 pp., diagrs., 10 x 7 in., paper. $3.36.

A treatise on the theory of elasticity and the strength of materials, intended for persons, especially for engineers, who already have an acquaintance with the subject and who are professionally interested in researches upon it. It offers to those familiar with the solution of the simpler problems further light on problems of stress and strain, which will enable them to understand the results of advanced research and apply them to the more complex problems.

The new edition has been corrected throughout, the results of recent investigations have been included and several new paragraphs have been added.

ELECTRICITY AND MAGNETISM.

By Sydney G. Starling. Fourth edition. Lond. & N. Y., Longmans, Green & Co., 1924. 612 pp., diagrs., 8 x 5 in., cloth. $4.00.

A textbook for senior students which is designed to give an adequate knowledge of the present state of the subject, with due reference to the historical sequence of its development and to the effect of modern research upon it. Covers the ground usually included in college courses and emphasizes theory rather than technical details or designs of machinery. This edition has been modified to accord with recent developments.

ELEKTRISCHE HOCHSPANNUNGSZUNDAPPARATE.

By Viktor Kulebakin. Berlin, Julius Springer, 1924. 90 pp., diagrs., 10 x 6 in., paper. $1.00.

The development of the internal combustion engine has been accompanied by a widespread production of high-tension ignition apparatus, but although millions of these devices are in daily use, there has hitherto been, this author states, no thoroughgoing study of their working process. The present work, based on extended theoretical and experimental investigations by the author, attempts to throw light on the problem.

FACTORY MANAGEMENT.

By Henry Post Dutton. N. Y., MacMillan Co., 1924. 329 pp., illus., charts, tables, 8 x 5 in., cloth. $2.75.

In this work the author attempts to give a balanced description of the operation of the several departments of a factory and to show their relation to each other and their problems as part of the greater problem of coordinating all the activities of the organization toward the accomplishment of a single purpose. The book is an effort to collect the different theories and methods of production control and form from them a connected philosophy of control. The author tries to present the viewpoint of the owner and manager, as well as that of the specialist.

FUNDAMENTALS OF RADIO.

By James L. Thomas. N. Y., D. Van Nostrand Co., 1923. 207 pp., illus., diagrs., 8 x 5 in., cloth. $1.50.

An elementary exposition of the theory underlying the operation of radio apparatus, intended as a textbook for operators and mechanics, both professional and amateur. The author avoids the use of mathematics, when possible, and explains matters in non-technical language.

GYROSCOPE; ITS PRACTICAL CONSTRUCTION AND APPLICATION.

By P. P. Schilovosky. Lond., E. & F. N. Spon, 1924. 224 pp., illus., diagrs., tables, 9 x 6 in., cloth. 14 s.

This volume is in three sections. The first treats of the mechanics of the gyroscope, discussing the three-framed and the two-framed gyroscope, the precessing spinning-top and gyroscopic systems of locomotion. Section two is devoted to monorail locomotion. The final section is a mathematical study of the theory of the monorail car, excerpted from the publications of P. T. Papkovitch. The author writes from the viewpoint of the inventor, in simple, non-mathematical fashion.

INTEREST AS A COST.

By Clinton H. Scovell. N. Y., Ronald Press Co., 1924. 254 pp., 8 x 5 in., cloth. $2.50.

Interest on investment may be included in the selling price of an article either as part of its cost or of the profit, if a business is to succeed. The present author considers interest a proper part of cost, and his book is written to present the reasons for this conclusion.

The theory supporting his position is given, and the attitude of those in favor of it are set forth. The various objections to this view of interest are also given and answered specifically. The book should prove of interest to all students of cost accounting.

INTERNATIONAL CITIES AND TOWN PLANNING EXHIBITION.

English Catalogue. Jubilee Exhibition, Gothenberg, Sweden. 389 pp., illus., plans, 10 x 7 in., paper. $2.00.

The Jubilee Exhibition at Gothenberg in 1923 brought together an interesting collection of data on town planning from eighteen countries and this catalog will be of interest to architects and engineers because of its historical and descriptive notes and its profuse illustrations. The latter include ancient and modern plans and pictures showing the development of street and housing all over the civilized world.

INTRODUCTION TO WIRELESS TELEGRAPHY AND TELEPHONY.

By J. A. Fleming. Lond. & N. Y., Isaac Pitman & Sons, 1923. 112 pp., illus., diagrs., 7 x 5 in., cloth. $1.00.

Dr. Fleming offers the general reader with some small acquaintance with electricity, a brief sketch of the general principles of wireless telegraphy and telephony as operated today. The book will also serve as an introduction to more advanced works.

IONEN UND ELEKTRONEN.

By H. Greinacher. Leipzig u. Berlin, B. G. Teubner, 1924. 58 pp., 9 x 6 in., paper. .42.

A brief introduction to the subject, prepared to fill the need arising from the increasing industrial use of electron tubes. The author discusses volume ionization, the measurement of the ion flow, properties of ions, surface ionization, the law of free ions, the use of electron tubes.

LINE CHARTS FOR ENGINEERS.

By W. N. Rose. N. Y., E. P. Dutton & Co., 1923. (Directly-Useful Technical Series). 95 pp., tables, 9 x 5 in., cloth. $3.00.

Intended to call the attention of engineers to the possibilities of charts as aids to calculation and especially to show how charts may be most easily made from formulas. Little knowledge of mathematics is required. The examples are taken from engineering practise. The greater part of the book relates to nomograms, but some examples of intercept charts are also included.

MANAGEMENT ENGINEERING.

By P. F. Walker. N. Y., McGraw-Hill Book Co., 1924. 359 pp., illus., 9 x 6 in., cloth. $3.50.

This textbook, prepared for classroom use by students of engineering, is intended as an introduction to all the various economic subjects of which an engineer should have some knowledge. It is designed to introduce the student to the main principles that underlie business procedure and to lead to more extended specialized treatises. A bibliography is included.

MANPOWER IN INDUSTRY.

By Edward S. Cowdrick. N. Y., Henry Holt & Co., 1924. 388 pp., 8 x 5 in., cloth. School edit. $2.50; trade edit. $3.25.

The purpose of the author is to present the principles underlying human relationships in industry and the more important methods that have been used in dealing with practical problems of personnel administration. The needs of the business executive and director of industrial relations, as well as those of students, have been kept in mind. The author discusses the principal labor problems of today.

MARINE BOILER MANAGEMENT AND CONSTRUCTION.

By C. E. Stromeyer. 6th edition. Lond. & N. Y., Longmans, Green & Co., 1924. 398 pp., illus., diagrs., tables, 9 x 6 in., cloth. $7.00.

The sixth edition of this well-known treatise on the manufacture and management of marine boilers has been considerably revised and enlarged. Notes have been introduced about electric welding and other new topics, and the results of recent study on heat losses, on the strengths of furnaces and flat plates and on similar matters of importance. The book is practical in character and presents the conclusions of an engineer with wide experience in the subject.

PRINCIPLES OF ELECTRIC MOTORS AND CONTROL.

By Gordon Fox. N. Y., McGraw-Hill Book Co., 1924. 499 pp., illus., diagrs., 8 x 5 in., cloth. $3. 50.

Differs from most texts on electric motors and controllers by emphasizing matters of application and operation rather than those of design. The book describes the principles, characteristics, performance and construction of this apparatus, and is intended to aid in the selection of suitable apparatus for a given purpose and its proper application. The text is simple and practical in character. Higher mathematics is avoided. Numerous short bibliographies are included.

PRINCIPLES OF ELECTROPLATING AND ELECTROFORMING.

By William Blum and George B. Hogaboom. N. Y., McGraw-Hill Book Co., 1924. 356 pp., illus., tables, 9 x 6 in., cloth. $4.00.

Contents:—Methods of expressing conditions of operation. Principles of chemistry. Elementary principles of chemical analysis. Principles of electricity. Principles of electrochemistry. Factors governing the character of the deposits. Selection, specification and inspection of electrodeposits. Preparation for electroplating. Preparation for electroforming. Electrical Equipment. Tanks and their equipment. Copper deposition. Nickel deposition. Cobalt and iron deposition. Deposition of zinc and cadmium. Lead and tin deposition. Silver deposition. Gold and platinum deposition. Deposition of alloys. Experiments in electrodeposition. Appendix: Tables.

The authors of this work have been associated for several years with the investigation of electrotyping processes at the Bureau of Standards. This experience has shown them that there is need for an account of the fundamental principles of the sciences related to these subjects, which will assist those engaged in the industry to understand and apply the results of the specific investigations undertaken by various research and educational institutions. The present volume is prepared with that object rather than to present the results of research.

PULVERIZED FUEL, COLLOIDAL FUEL, FUEL ECONOMY AND SMOKELESS COMBUSTION.

By Leonard C. Harvey. Lond., Macdonald & Evans. 1924. (Reconstructive Technical Series) 466 pp., illus., diagrs., tables, 10 x 7 in., cloth. 2/2/0. (Gift of the Author)

The author of this volume was sent to America during the Great War, to study methods of fuel economy for the British Fuel Research Board. His investigations at this time and the results of his continued study in the intervening years are now brought together in the present work. Mr. Harvey has written a comprehensive technical and practical treatise descriptive of the various pulverized fuel systems, machinery and applications, which exhibits the present state of the art in very satisfactory fashion. Much information on costs of installation and operation is included, as well as on the results obtained in various countries and an extensive selected bibliography is given.

RECEPTION DES SIGNAUX HORAIRES.

By France. Bureau des Longitudes. Paris, Gauthier-Villars et Cie., 1924. 226 pp., diagrs., tables, 10 x 6 in., paper. 27 fr.

This book, issued by the Bureau des Longitudes is not designed to describe, even generally, all the methods now in use for broadcasting and receiving radio messages. It does, however, give much useful information on the methods and receiving apparatus which are of direct interest to scientists, sailors, aviators and meteorologists, and it furnishes detailed instructions for utilizing radio to distribute time, to determine differences in longitude, and to diffuse meteoroligical, seismological and other scientific information.

TASCHENBUCH FUR DEN MASCHINENBAU.

By H. Dubbel. Ed. 4. Berlin, Julius Springer, 1924. 2 v., illus., diagrs., tables, 8 x 5 in., cloth. $4. 30.

A concise work of reference for mechanical engineers, covering mathematics, mechanics, fuels, materials, machine elements, power plants, prime movers, hoisting and conveying machinery, machine tools, and electricity. Mathematics and mechanics are thoroughly treated, with special attention to principles, and with numerous examples of the practical use of important formulas. The practical part was prepared with special considerations of the machine designer and builder, to whom it gives a quick survey of those topics outside his special field and an acquaintance with the most important methods and numerical data. The book is the joint effort of a number of specialists.

DIE TECHNISCHE CHLORALKALI-ELEKTROLYSE.

By J. Billiter. Dresden u. Lpz., Theodor Steinkopff. 1924. 80 pp., diagrs., tables, 9 x 6 in., paper. .60.

This monograph is a concise presentation of the principles of the various electrolytic methods for making chlorine, caustic alkalies, hypochlorites, chlorates and perchlorates, together with special reference to the processes that have been commercially successful in recent years and to the modern development of the industry as a whole.

TREATISE ON LIGHT.

By R. A. Houston. New edition. Lond., & N. Y., Longmans Green & Co., 1924. 486 pp., illus., diagrs., tables, 9 x 5 in., cloth. $4.00.

A textbook for students who have had training in physics and are proceeding further with the study of light. It differs from other books on light by a more systematic treatment, also by dealing with the full scope of the subject and including the results of recent investigations. The new edition is corrected and has an added chapter on recent advances.

TULLEY'S HANDBOOK; STEAM AND ELECTRICAL.

By Henry C. Tulley. 7th edition, rev. & enl. by James F. Hobart. N. Y., McGraw-Hill Book Co., 1924. 3 v., illus., diagrs., tables, 8 x 5 in., cloth. $7.50.

A handbook for men engaged in the operation of power plants as engineers, firemen, mechanics, etc. Explains the theory, construction, operation and maintenance of power plant machinery in simple, practical fashion.

UNITED STATES EMPLOYMENT SERVICE.

By Darrell H. Smith.

PATENT OFFICE.

By Gustavus A. Weber.

OFFICE OF EXPERIMENT STATIONS.

By Milton Conover.

(Institute for Government Research. Service monographs of the U. S. Government, nos. 28, 31 & 32). Balto., Johns Hopkins Press, 1923 & 1924. 9 x 6 in., cloth. $1.00 each.

Like previous volumes of this series, these monographs explain in detail the history, development and functions of the government services to which they refer. The studies are prepared on a uniform plan and are descriptive, not critical; their purpose being to furnish accurate accounts of the services, their equipment, cost and achievements.

WIRING FOR LIGHT AND POWER.

By Terrell Croft. 4th edition. N. Y., McGraw-Hill Book Co., 1924. 551 pp., illus., diagrs., 8 x 5 in., fabrikoid. $3.00.

A commentary on the National Electrical Code, which supplies explanations, elaborations and illustrations for the sections to which it is necessary to refer most frequently. The text of these sections is given verbatim and followed by the supplementary text and drawings. The reasons for the code rules are thoroughly discussed.

This edition has been completely rewritten, to conform to the rearranged and revised "1923 Code."

LIBRARY LOANS STIMULATE BOOK BUYING

The members who are borrowing books from the Library under the new loan plan are availing themselves of the privilege of purchasing the books to an unexpected degree. The Library practically sends out books on an approval plan similar to that used by some publishers. If the borrower finds that the book sent will be of permanent use to him he can send to the Library the amount for which the book has been insured, as this is equivalent to the publisher's price, and the book becomes his property. If there is only a temporary need for the book, it may be retained as long as required and then returned to the Library. For this a rental of five cents a day is charged after the allowance for time in transit has been deducted.

The Library hopes to serve by this plan the members who are removed from large collections of engineering books. By retaining the books which they find helpful, a small working collection will soon be secured. It also offers them an opportunity to keep informed concerning developments in various fields of engineering.

Requests for loans should be addressed to the Engineering Societies Library, 29 West 39th Street, New York. N. Y.

PERSONAL MENTION

ANDERS OXEHUFWUD has accepted a position as Designer with the Utica Gas and Electric Company, Utica, N. Y.

EDWARD J. BRANNIGAN, formerly Sales Engineer, Westinghouse Elec. & Mfg. Co., Buffalo, N. Y., is now located with the Maloney Electric Co., St. Louis, Mo.

J. B. SILVERMAN is now connected with The Ohio Edison Company, Springfield, Ohio, having severed his connections with The Union Gas and Electric Company.

J. IRWIN MOORE has accepted a position with the Electric Storage Battery Company as an erecting engineer, after resigning from the Philadelphia Electric Company.

H. H. KERR has recently been appointed Superintendent of the Electrical Department of the Public Service Company of Colorado, succeeding Donald C. McClure.

FRED J. W. LUCK is now Territorial Manager with the Westinghouse Electric International Company, 2 Norfolk St., Strand, London, England. Mr. Luck was formerly Special Representative in Rio de Janiero, Brazil, S. A.

R. P. MCCLELLAN is now employed by the West Penn Company, Pittsburgh, Pa. in the capacity of Division Engineer of the Brooke Division with headquarters at Wellsburg, W. Va.

PLINY P. PIPES resigned his position as Welding Engineer with the Lincoln Electric Co. and is now associated with the Ohio Brass Co., as Development Engineer Mansfield, Ohio.

GEORGE R. HEFNER has left the Cline Electric & Mfg. Co. and is now connected with the Cutler-Hammer Mfg. Co., Printing Equipment Department, Times Bldg., New York City.

HAROLD K. LOWRY is now connected with the Sprague Safety Control and Signal Corporation, Chicago, Ill., having left the employ of the Chicago Rock Island & Pacific Railway.

JOHN H. DONAHUE, formerly with Abbott-Merkt & Co., Tullytown, Pa., has accepted a position as Electrical Superintendent with the Phoenix Utility Co., New Orleans, La.

GANO DUNN, Past President of the Institute, was recently re-elected Chairman of the National Research Council. He has also been elected to membership in the American Philosophical Society.

K. V. FARMER, is now Electrical Engineer with the Schiefer Electric Co., 614 City Bank Bldg., Syracuse, N. Y., having resigned his position as Supt. of the Electric Dept. of the Syracuse Lighting Co.

HENRY C. WALTER, formerly in the engineering department of the Allis-Chalmers Mfg. Co., has accepted the position of Engineer in charge of d-c. design with Fairbanks Morse & Co., Indianapolis, Ind.

J. STANLEY BROWN is now Electrical Designer, Dwight P. Robinson & Co., Inc., Seal Beach, Calif. He accepted this position after severing his connections with the Phoenix Utility Co., New Orleans, La.

G. METCALFE SIMONSON, formerly Chief Electrical Engineer, State Dept. of Public Works, Sacramento, California, has now become a member of the firm of Simonson & St. John, Flatiron Bldg., San Francisco, Calif.

DAVID D. GIBSON, JR., who has been serving as Field Engineer of the Springdale Power Station for Sanderson & Porter Corp., has resigned, and will become connected with The Dixie Construction Co. of Birmingham, Ala.

MARCEL M. GOLDEN has been appointed by his company, Constructions Electriques de France, Paris, as Chief Engineer in connection with their Spanish agency in Madrid in charge of railway electrification and hydroelectric power plants.

Einar A. Brofos has resigned his position as Managing Director of the Western Electric Norsk Aktieselskap, Christiania to become European Commercial Manager of the International Western Electric Company, Inc., Connaught House, Aldwych, London.

Fred C. DeWeese has resigned his position as General Superintendent of the Eastern Minnesota Power Company, Pine City, Minn., and is now connected with the Louisville Gas & Electric Co., Louisville, Ky. in the Distribution and Construction Department.

Herbert W. Kidwell resigned his position with the Washington & Old Dominion Railway as Electrical Engineer to take the position of Southern Department Manager of the National Railway Appliance Co. of New York City, with headquarters in the Munsey Bldg., Washington, D. C.

Justin L. Fearing, formerly a member of the Examining Staff of the U. S. Patent Office, and subsequently associated for several years with the Patent Department of the Western Electric Co., Inc., has opened an office at 31 Milk St., Boston, Mass., specializing in soliciting patents.

William Elsdon-Dew, consulting engineer of Johannesburg, and Local Honorary Secretary of the Institute in South Africa, attended the meeting of the Institute in New York, May 16, during a few weeks' visit to the United States before departing for the World Power Conference in London.

Robert Baird Williamson, Electrical Engineer in charge of alternating current design of the Allis-Chalmers Mfg. Co., sailed on April 26th for a two months' trip to the British Isles and the Continent. During his trip Mr. Williamson will inspect European engineering developments and will attend the British Empire Exposition at Wembly.

Alfred D. Flinn, Director of Engineering Foundation, has been made an honorary foreign member of the Masarykova Akademie Prace, of Prague, as a token of appreciation for helpfulness extended by the Foundation and an expression of goodwill toward American engineers. The election by the Academy was approved by decree of the government of the Republic of Czechoslavakia, given through its Minister of Foreign Affairs.

Allen H. Babcock, research engineer for the Southern Pacific Company, and for the past three years identified with the American Radio Relay League as a Pacific Coast director, has been appointed by President Coolidge, on recommendation of Secretary of Commerce Hoover, as one of a committee of three to represent the United States in a radio conference to be held at Mexico City, beginning May 26.

Henry A. Lardner, Fellow of the Institute and Vice-President of the J. G. White Engineering Corporation, has been elected mayor of Montclair, N. J. There were five commissioners elected at the municipal election held May 13, and Mr. Lardner received the highest vote of the eighteen candidates. The newly elected commissioners, at their organization meeting on May 20, elected Mr. Lardner to the office of mayor.

Elihu Thomson sailed April 26th on the Comte Verdi for a three months' tour of European countries. While abroad, he will receive the Lord Kelvin gold medal, which was recently awarded to him. The presentation will be made early in June at London, England. This award, made through joint action of British and American engineering societies, occurs every three years and is a mark of distinction for excellence in research work in engineering. Prof. Thomson is the first American to receive the honor.

Walter D'Arcy Ryan, head of the General Electric illuminating engineering laboratory, has recently been awarded a grand prize for the electrical illumination of the Brazilian Centennial Exposition, held at Rio de Janeiro in 1922, as collaborator with the General Electric Company of South America; and also an individual prize in recognition of his work as Director of Illumination, particularly for the effects he secured with his Novagem jewels of various colors. Mr. Ryan was selected for this work as a result of his success with similar work at the time of the Panama-Pacific International Exposition.

Paul C. Sorsby leaves Japan via Paris for New York in June. Mr. Sorsby came to Japan via Vancouver in March 1922 in the interests of the International General Electric Company as engineer in charge of steam turbo alternator erection and complaints. He and his assistant, Mr. Okuma, were in Yokohama at the time of the earthquake last September. Although falling three stories in a brick building, Mr. Sorsby managed to make his escape only a few minutes before the fire reduced the entire city to ashes. Mr. Okuma was killed in the crash but fortunately Mr. Sorsby escaped with but slight bruises. Mr. Sorsby has been associated with the General Electric Company in various capacities since 1910 and has been a member of the Institute for a number of years.

Obituary

Chester T. Allcutt, an Associate of the Institute, died on March 10, 1924. Mr. Allcutt graduated from Stanford University in 1915, and later became Research Engineer with the Westinghouse Electric and Mfg. Co., East Pittsburgh.

Theodore Vladimiroff, electrical engineer, died the latter part of February after a week's illness. Mr. Vladimiroff was born in Bulgaria and educated at the American Institute at Samokove, later coming to America to the University of Michigan. Since 1904 he has been connected with the firm of Martin C. Schwab, Chicago, Ill. Mr. Vladimiroff became an Associate of the Institute in 1908.

Henry C. Egerton, inventor and engineer, died on Feb. 18, 1924. For many years he was connected with the Western Electric Co., New York City, in various capacities, during which time he contributed many inventions to the industry, including telephone apparatus and circuits.

In 1910 Mr. Egerton graduated from Cooper Union with a B. S. degree and in 1912 was awarded the degree of Electrical Engineer.

After leaving the Western Electric Co., he formed a company of his own; and in 1920 became General Manager of the Edison Storage Battery Co., West Orange, N. J.

Mr. Egerton became a Member of the Institute in 1918.

Elmer K. McDowell died suddenly of acute dilation of the heart on March 19, 1924 at the offices of the Donora Steel Works, Donora, Pa. Mr. McDowell was a graduate of Pennsylvania State College. He was connected with various firms as draftsman, designer and estimator, later becoming Chief Works Manager and Chief Drafting Engineer for the Donora Steel Works, which position he held at the time of his death.

Mr. McDowell was an accomplished musician and the author of numerous technical treatises. He was a member of the American Society of Mechanical Engineers and recently became an Associate of the Institute.

Henry M. Byllesby died on Thursday, May 1, 1924 after being seriously ill for several months with heart trouble. Colonel Byllesby was born in Pittsburgh, February 16, 1859. He studied at the Western University of Pennsylvania in 1871-73 and at Lehigh University 1873-77. In 1879 he entered the drafting office of Robt. Wetherill & Co., manufacturers of Corliss engines. On June 1, 1881 he entered the service of the Edison Company for Isolated Lighting, New York, as draftsman on plans of the first power station in the U. S., the Pearl St. station. Leaving the Edison Co. in 1885, he became associated with the

Westinghouse Co. on November 1st and in association with Westinghouse, Stanley and others produced in 1886 the first commercial a-c. lighting apparatus. Subsequently, he was associated among others with the Thomson Houston Co., the U. S. Elec. Lt. & Pr. Co. and the Electric Vehicle Co. In 1902 he established in Chicago the organization of H. M. Byllesby & Co., Inc., of which he was president. Within a few years this organization became prominent in the financing, designing, construction, operation and management of electric and gas companies. Mr. Byllesby entered the Institute as an Associate in 1904, became a Member in 1912 and a Fellow in 1920. He was a member of the Edison Medal Committee 1920-24.

Charles E. L. Brown, organizer and head of Brown, Boveri & Co., Switzerland and Honorary Member of the Institute, died on May 3, 1924, after a short illness at his home in Montagnola, Switzerland. Dr. Brown who was born in Winterthur, Switzerland in 1863, entered the service of the Oerlikon Engineering Works in 1883 and two years later became director of the electrical department. In 1886 he constructed a direct-current, high-tension line conveying 50 h. p. of hydroelectric power five miles into Solothurn, Switzerland. His next undertaking was the 600-h. p. Schoffhausen plant at the falls on the Rhine, employing two 625-volt d-c. generators in series. In 1888 Mr. Brown produced some exceptional electrolytic generators having outputs of 12,500 amperes at 20 volts. He later turned his attention to single-phase transformers and generators and when Tesla brought out his polyphase system, he recognized its application to long distance transmission at high-voltage and designed the first oil-insulated high-tension transformers. In 1890 he had a 40,000-volt test set in use. In 1891 Dr. Brown organized Brown, Boveri & Co., where he took up the development of the revolving-field type alternator. He developed numbers of machines, among them, a commercial single-phase motor, starting on the split-phase principle. He built a three-phase railway at Lugano in 1894, following it with those on the Gorner Grat, the Jungfrau and one at Thun. Dr. Brown was made an Honorary Member of the Institute in 1912.

Charles B. McLeer, designer, inventor and engineer, died on April 17, 1924 at St. Mary's Hospital, Passaic, N. J. Mr. McLeer was born in Brooklyn, N. Y. June 1, 1877 and received his education at the Brooklyn High School and Pratt Institute.

In 1897 he entered the employ of the Western Electric Co. and four years later became assistant engineer to Geo. T. Hanchett of the General Electric Inspection Co. In 1904 he was in charge of all engineering for the McLeer Engineering Co. and after a number of years became associated with the Electric Carrier Co. and the Electric Transportation Co., during which time he designed and constructed an experimental and demonstration plant at Paterson, N. J., proving the practicability of the Electric Carrier Method of propulsion for commercial use. He was also responsible for all plans, specifications and estimates, including those for an underground mail transportation system between Grand Central and Pennsylvania Stations in New York City. Mr. McLeer was the inventor of and held the patents on the McLeer Automatic Train Signal System, for use on electric and steam railways.

In 1920 he was in London, preparing a system of mail transit for the British Government. Upon his return he became associated with the Continuous Transit Co. as Construction Engineer in the building of the moving platform at Jersey City, and assisted in the design and construction of the inductive drive method of propulsion. In February of this year Mr. McLeer was appointed Vice President of the Company.

Mr. McLeer became a member of the Institute with the grade of Fellow in 1920.

Date of Annual Meeting of A. M. E. S. Changed

The date of the Annual Meeting of the Associated Manufacturers of Electrical Supplies and the Section Meetings, which had been fixed for the week beginning June 23, 1924, has been changed to the week beginning *Monday, June 16, 1924*, at the same place,—the Hotel Ambassador, Atlantic City, New Jersey.

Past Section and Branch Meetings

SECTION MEETINGS

Akron

Instrument Transformers, by E. S. Foster, Packard Electric Co. A number of interesting slides were shown. May 3. Attendance 70.

Atlanta

Crossing Bridges and Scaling Stone Walls, by C. E. Skinner, Westinghouse Electric & Manufacturing Co. The lecture was very interesting and instructive. April 4. Attendance 75.

Baltimore

Outstanding Developments in Radio, by Professor L. F. Hazeltine. The speaker gave a very interesting talk on radio receiving circuits and exhibited slides and several different types of receiving sets. Refreshments were served. February 15. Attendance 185.

Holtwood Power Development, by N. B. Higgins and R. L. Thomas.

Hydraulic Turbines and Draft Tubes, by F. H. Rogers.

The New Holtwood Construction, by J. Walter May. An inspection trip was made to the power plant at Holtwood, Pa. This meeting and inspection trip proved an exceptionally interesting one, as construction work was going on at that time. Joint meeting with A. S. M. E. March 1. Attendance 70.

Interconnection and Superpower, by Stevens T. Hayes. The talk proved to be very interesting and he illustrated many points with slides. Refreshments were served. March 21. Attendance 60.

Boston

Prediction of Insulation Failures in Transmission Lines, by C. L. Kasson, H. C. Hamilton and R. W. Chadbourne. The talk was illustrated with lantern slides. April 22. Attendance 70.

Value of Report by the Power Investigating Committee of the Associated Industries of Massachusetts to Industries: Cost of Power Production in Isolated Plants, by Charles T. Main.

Interconnection between Utilities in New England: Sources of Supply of Additional Hydro Power, by H. I. Harriman.

Comparison of Cost of Canadian Power and Steam Power Generated in New England, by Dugald C. Jackson. The meeting was preceded by a buffet supper. April 29. Attendance 300.

Cincinnati

Telephone Transmission, by H. S. Osborne, American Telephone & Telegraph Co. The speaker also gave a description of the radio, wire and submarine cable circuit from Catalina Islands off the Pacific Coast to Havana, Cuba. It was well illustrated with movies and lantern slides. March 13. Attendance 60.

Correcting Low Power Factor at the Source, by Bradley T. McCormick, Wagner Electric Corp. The speaker very clearly described the design and construction of the Fynn-Weichsel motor, also its operating characteristics. This talk was well illustrated with lantern slides. May 8. Attendance 61.

Cleveland

Analyzing Some of the Fundamentals of Engineering, by Chas. F. Kettering, General Motors Research Corp. Joint meeting with the Illuminating Engineering Society. April 24. Attendance 200.

Columbus

History of the Automatic Telephone, by C. A. Swoyer, Ohio Bell Telephone Co. The speaker's talk included a demonstration of the operation of the automatic telephone, showing the entire handling of a telephone call. Prior to the lecture the following motion picture films were shown: Pillars of the

Sky; Behind Your Telephone, and Telephone Inventors of Today. January 4. Attendance 34.

Japanese Power Systems, by S. T. Hayes, Westinghouse Elec. & Mfg. Co. The lecture was illustrated by several reels of motion pictures and a large number of slides. January 25. Attendance 26.

The Russian Revolution and Its Lessons to the American Engineers, by Professor C. A. Norman, Ohio State University. A noon-day luncheon preceded the talk. Joint meeting with the Engineers' Club of Columbus. February 9. Attendance 44.

Railway Electrification, by F. E. Wynne, Westinghouse Elec. & Mfg. Co. The lecture was illustrated with motion pictures and lantern slides. Joint meeting with Engineers' Club. February 15. Attendance 35.

Ventilation from the Medical Viewpoint, by Dr. E. A. Hayhurst, Ohio State University. This joint meeting with the Engineers' Club was in the form of a noon-day luncheon. February 23. Attendance 53.

Modern Street Lighting, by Professor F. C. Caldwell, Ohio State University. The talk was illustrated with lantern slides, showing the development and theory of street-lighting practise.

The Columbus Street-Lighting Demonstration, by M. S. Hopkins, Chairman of the Chamber of Commerce Committee on Street Lighting. After the discussion those present inspected the 11 sets of street-lighting equipment which have been installed in the business and residential sections of Columbus. Joint meeting with the Illuminating Engineering Society. April 11. Attendance 37.

Niagara Falls Power, by E. J. Wills, The Niagara Falls Power Co. In the afternoon an inspection trip was made through the plant of the Robbins and Myers Co. Joint meeting with the Springfield Engineers' Club. April 25. Attendance 102.

Denver

The Valmont Development of the Public Service Company, by H. H. Kerr, Public Service Co. of Colorado. The talk was illustrated by lantern slides. A dinner preceded the meeting. April 18. Attendance 95.

Detroit-Ann Arbor

The New Trenton Channel Plant, by P. W. Thompson, Detroit Edison Co.

The 120,000-Volt Transmission System, by A. A. Meyer. Both talks were well illustrated with pictures showing the details of the power plant, out-door bus-bars, transmission line, etc. Mr. Meyer gave a brief history of the development of the Detroit Edison Power System from 1904 to the present time. Joint meting with A. S. M. E. April 17. Attendance 275.

High-Voltage Line Insulators, by A. O. Austin, Ohio Insulator Co. The talk was illustrated with slides. May 8. Attendance 50.

Erie

Advantages of Belonging to the American Institute of Electrical Engineers, by Mr. Siebert.

Internal-Combustion Electric Locomotives, by H. Lemp, General Electric Co. The lecture was illustrated with a large number of lantern slides. The newly elected officers for the coming year are as follows: Chairman, B. L. Delack; Secretary, L. H. Curtis; Executive Committee, James Burke, M. P. Ames and Hermann Lemp. April 30. Attendance 129.

Fort Wayne

Asphaltic Highway Construction, by Geo. W. Craig, Middle Western Branch of the Asphalt Association. Two reels of motion pictures were shown. Refreshments were served. March 27. Attendance 50.

Electricity Supply Industry and The Engineer, by R. F. Schuchardt. Following the talk, a committee was appointed to investigate the construction of the Maumee River dam, now being built by the City of Fort Wayne, and the power facilities of the river. Refreshments were served. April 17. Attendance 62.

Ithaca

Cooperation in the Electrical Industry, by F. M. Feiker. April 25. Attendance 160.

Kansas City

A lecture was given by Dr. R. C. Moore on his recent trip through the Grand Canyon and was illustrated by moving pictures. The meeting was followed by an informal dance. Joint meeting of various Engineering Societies, under the auspices of A. I. E. E. and Engineers' Club of Kansas City. April 26. Attendance 140.

Lehigh Valley

Supervisory Control of Power Circuits, by C. E. Stewart, General Electric Co. The talk was illustrated by lantern slides and a very ingenious moving picture, showing the wiring connections and operation of the apparatus. Mr. J. L. McCoy, Westinghouse Electric & Mfg. Co., covered the same subject and illustrated his talk by a model equipment showing very clearly how this new system of control is operated. Preceding the meeting, dinner was served. The following officers were elected for the new year: Chairman, Professor J. L. Beaver; Secretary-Treasurer, G. W. Brooks; Executive Committee, A. L. Wagner, W. H. Lesser and W. W. Perry. May 8. Attendance 61.

Lynn

An inspection trip was made to the fortifications which guard Boston harbor. April 12. Attendance 300.

Mercury-Vapor Process, by Edward V. Pollard. Mr. E. D. Dickinson, General Electric Co., showed a number of lantern slides of the Mercury Turbine Plant at Hartford, Conn., and explained some of the details of construction peculiar to the operation of the mercury turbine.

Advantages of Using High Pressure and Superheated Steam, by Albert G. Gale. April 16. Attendance 75.

Close Limits in Shop Work, by B. H. Blood, Pratt & Whitney Co. April 23. Attendance 250.

The National Forests, by Philip W. Ayres. April 30. Attendance 125.

Local Street-Railway Problems, by W. Whiteford, Twin City Rapid Transit Co. March 24. Attendance 33.

My Trip through Africa, by Thomas Duncan, Duncan Electric Co. April 28. Attendance 80.

Electrolysis, by John E. F. Zink, Oklahoma Natural Gas Co.

The Conversion of the Tulsa Telephone System from Manual to Machine Switching, by D. C. Bacon, Southwestern Bell Telephone Co.

Travelogue on South America, by Calvin W. Rice, Secretary, A. S. M. E. The following officers were elected for the coming year: Chairman, T. M. Fariss; Vice-Chairman, R. B. George and E. R. Page; Secretary-Treasurer, A. D. Stoddard. April 26. Attendance 27.

New York

The Atmosphere As a Factor in Electrical Engineering, by President Harris J. Ryan. This meeting was held in connection with the Annual Business Meeting of the Institute, an account of which is given elsewhere in this issue. May 16. Attendance. 175.

Philadelphia

Railroad Electrification—Its Present Development and Future, by J. Van Buren Duer, Pennsylvania Railroad System. Mr. Duer not only traced the history of the electric locomotive from its early inception up to the present day but summarized the possible economies of electric operation. This subject was also discussed by Messrs. H. K. Smith, L. F. Deming, W. K. Vanderpoel, F. J. Chesterman, Dewhurst, Schute, H. C. Albrecht and N. E. Funk. April 14. Attendance 1000.

Pittsfield

Institute Activities in District No. 1, by C. Faccioli. The speaker briefly told of the coming first regional convention to be held in Worcester, June 4 and 5.

The Relation of the Engineer to His Profession, by H. B. Smith. Mr. Daniel J. Sullivan also entertained the Section with "lightning" calculations. Annual Dinner. March 27. Attendance 119.

Recent Developments in Small Arms, by Major Earl McFarland of the Ordnance Department of the U. S. A. April 10. Attendance 125.

Electric Transmission and Reproduction of Sound, by W. H. Martin, American Telephone and Telegraph Company. The speaker discussed the requirements for good reproduction, general operation of systems for the electric transmission and reproduction of sound, the characteristics of sounds, and the more common causes of distortion. He demonstrated these features by means of a typical broadcasting studio and receiving station. May 1. Attendance 250.

Providence

The Super-Heterodyne, by Major E. H. Armstrong, Columbia University. The talk, which was well illustrated by lantern slides, covered the conception of the idea of the super-heterodyne and the development of this circuit to its present state. Joint meeting with the A. S. M. E. and the Radio Section of the Providence Engineering Society. May 2. Attendance 350.

Rochester

Education and Development of Men for the Industry, by P. M. Lincoln, Cornell University. April 4. Attendance 60.

The Measurement of Management, by Joseph W. Roe, New York University. The following officers were elected for the coming year: Chairman, F. T. Bryne; Vice-Chairman, H. C. Ward; Secretary-Treasurer, E. A. Reinke; Executive Committee, A. Soderholm, Elmer E. Strong, Roger DeWolf and H. L. Gordon. Joint meeting with A. S. M. E. and Rochester Engineering Society. May 2. Attendance 65.

St. Louis

Rigid Airships in War and Peace, by Starr Truscott, Naval Bureau of Aeronautics. The talk was very instructive and was well received by everyone. The following officers were elected for the new year: Chairman B. D. Hull; Secretary, Chris H. Kraft. April 23. Attendance 124.

San Francisco

General Electric Company's Pacific Coast Broadcasting Station "K G O," by R. C. Koernig. Those present made an inspection trip to the General Electric Company's "K G O" Broadcasting Station in Oakland. March 28. Attendance 250.

Automatic Stations and Their Remote Supervision, by Chester Lichtenberg, General Electric Co. The speaker accompanied his talk with a number of lantern slides and two moving pictures, which illustrated the subject by means of animated diagrams. April 25. Attendance 135.

Seattle

The Public Address Systems, Their Applications and Use on the Pacific Coast, by C. N. Cole, Pacific Telephone & Telegraph Co. April 16. Attendance 47.

Spokane

An Outline of the Advance in the Art of Hydroelectric Power-Station Construction, by R. L. Hearn, Washington Water Power Co. This talk was illustrated by lantern slides.

The New Oak Grove of the Portland Railway, Light & Power Co., by D. W. Proebstel, Portland Railway, Lt. & Pr. Co. This was illustrated by lantern slides and motion pictures. April 25. Attendance 35.

Springfield

High-Voltage Phenomena, by G. Faccioli, General Electric Co. A banquet preceded the meeting. April 21. Attendance 75.

Toledo

Application of Electrical Apparatus to the Stone Industry, by D. W. Yambert. April 25. Attendance 19.

Toronto

Present-Day Application of Radio Communication, by W. C. C. Duncan. The speaker reviewed the history of wireless communication. April 11. Attendance 100.

Geology from a Motor Car, by Professor A. P. Coleman, University of Toronto. The speaker described a trip across the continent in a motor car. The following officers were elected for the year 1924-25: Chairman, H. C. Don Carlos; Secretary, W. L. Amos; Executive Committee, O. V. Anderson, L. B. Chubbuck, M. B. Hastings, M. J. McHenry, C. E. Sisson and A. R. Zimmer. April 24. Attendance 64.

Worcester

The Inductive Coordination Movement, by W. V. Lowell, National Electric Light Association, and D. H. Keyes, American Telephone & Telegraph Company. April 24. Attendance 50.

BRANCH MEETINGS

University of Alabama

Talk by Professor F. R. Maxwell, Jr., on the papers presented at the A. I. E. E. Convention in Birmingham. April 15. Attendance 8.

University of Arkansas

Possibilities of the Trackless Trolley, by Joel Blake.

Electric Boilers, by T. E. Fisher.

Heat Treatment of Steel, by C. E. Bowman. May 7. Attendance 10.

Bucknell University

Automatic Control of Electrical Substations, by W. H. Rodney, General Electric Co. The lecture was accompanied by slides and moving pictures. April 29. Attendance 76.

California Institute of Technology

Commercial Radio, by W. L. Holloday, student. April 9. Attendance 25.

University of California

The Klydonograph and Its Application as a Photographer of Power Line Surges, by A. W. Copley, Westinghouse Elec. & Mfg. Co. Mr. J. F. Peters, the inventor of the Klydonograph, was present and added to the discussion in such a way as to make the exposition a most interesting one. April 9. Attendance 55.

Catholic University of America

Electrical Porcelains, by Professor T. S. McKavanaugh. The lecture was illustrated by slides. Refreshments were served. May 5. Attendance 28.

University of Cincinnati

"Dies" in the Electrical Shops, by Lester Bosch, student. April 3. Attendance 38.

Grounded Transmission Systems, by C. T. Button, student. April 10. Attendance 36.

Clemson Agricultural College

Electricity, the Wonder Worker, by J. H. Sams. Slides accompanied the lecture. April 21. Attendance 23.

Colorado Agricultural College

The New Atomic Theory and the Theory of Ether Waves, by Professor H. G. Jordan. April 14. Attendance 10.

University of Colorado

Super-Power, by Dean H. S. Evans. April 2. Attendance 55.

Valmont Development of the Public Service Company, by H. H. Kerr, Public Service Company of Colorado. The lecture was illustrated with lantern slides. April 18. Attendance 85.

Denver University

Effects of Certain Impurities in Storage-Battery Electrolytes, by R. A. Silver, student.

The 65,000-Kv-a. Generator of The Niagara Falls Power Company, by T. R. Cuykendall, student.

Experimental Analysis of Stability and Power Limitations, by C. C. Herskind, student.

Nature of Language, by T. Hourichi. May 2. Attendance 15.

State University of Iowa

Porcelain Insulators, by A. N. Stanton.

Installation of 66-Kv-a. Cable, by A. Williams.

A Universal Meter for Measuring Power, by F. J. Zara. April 14. Attendance 45.

Central Heating Plants, G. B. Nichols. Consulting Engineer. April 28. Attendance 50.

Talk by Calvin W. Rice, Secretary, American Society of Mechanical Engineers. May 5. Attendance 45.

Lafayette College

The Electron Tube and Its Various Uses in the Commercial World, by Professor King. April 4. Attendance 20.

The Uses of the X-Ray Tube, by Professor King. The lecture was followed by a moving picture covering the same subject. April 26. Attendance 20.

Automatic Sub-Stations, by Mr. Rowney, General Electric Co. The lecture was illustrated with slides and a moving picture. April 30. Attendance 20.

Marquette University

The students visited the Meter-Testing Division of the Milwaukee Electric Railway & Light Company. Mr. J. E. Miller gave a talk in which he outlined the scope of this department. April 10. Attendance 28.

Engineering School of Milwaukee

Meter Testing, by J. E. Miller, Milwaukee Electric Railway and Lighting Co. The lecture was followed by a very instructive trip through the meter-testing laboratories.

Michigan Agricultural College

The officers elected for the coming year are as follows: Chairman, C. M. Park; Secretary-Treasurer, O. Dausman; Executive Council, C. Brongersma, K. DeGraw and L. Dewey. March 19. Attendance 18.

Super Power, by R. H. Boyle, student.

The St. Lawrence Waterway, by F. R. Wightman, student.

Dry-Cells and Storage-Battery Vacuum Tubes, by Mr. Osborn, Instructor.

Loud Speakers, by F. Pacholke, student. Mr. Pacholke gave a demonstration of several designs of loud speakers. April 22. Attendance 27.

University of Missouri

The Young Engineer's Problem of Fitting Himself into Established Procedure, by Everett S. Lee, General Electric Co. April 22. Attendance 26.

University of Nebraska

The Life of Dr. Steinmetz, by Dean O. J. Ferguson. Officers elected for the coming year are as follows: Chairman, Dean O. J. Ferguson; Secretary, Professor O. E. Edison; Student Chairman, H. J. Edgerton, Student Vice-Chairman, R. R. Schindler; Student Secretary, A. O. Andrews; Student Treasurer, Harry Moyer. May 1. Attendance 30.

University of North Carolina

The Mercury-Vapor Boiler and Turbine as Developed by W. R. Emmet of the General Electric Company, by Professor Hoeffer. The speaker explained its many good points, at the same time pointing out several features which may prevent its use ever becoming as common as the steam type. May 8. Atetndance 25.

Ohio Northern University

Tapping High-Voltage Lines for Low-Voltage Local Service, by Mr. Buchwalter.

Fundamental Principles of Radio Communication, by Mr. Upp. April 24. Attendance 22.

University of Pittsburgh

Mr. F. Wills gave a Report of the meeting of the Pittsburgh Section, describing the development, construction, operation and application of the Klydonograph.

Current Events in the Electrical Field, by W. R. Coleman.

Present Trend of Electrical Safety in Coal Mines, by A. C. Stambaugh. April 11. Attendance 25.

Cadet Course with the West Penn Power Company, by L. J. Crandall. The speaker described the nature of the work and the division of time in each of the various departments during the training period for the technical graduate. April 25. Attendance 25.

G. E. Alternating-Current Equipment, by G. H. Campbell. The lecture was illustrated with slides showing the manufacture and construction of the electrical apparatus in the shop. May 9. Attendance 20.

Rhode Island State College

Electric Welding and the Heat Treatment of Steel, by H. Raymond Little. April 9. Attendance 20.

Electrification of the Chicago, Milwaukee and St. Paul Railroad, by Matthew Chappell. A motion picture, entitled "The King of the Rails," was also shown. April 24. Attendance 19.

Stanford University

Mr. M. L. Wiedman was elected Chairman to succeed Mr. Bumbaugh, resigned. April 8. Attendance 17.

Business meeting. April 22. Attendance 12.

Communication Engineering, by C. F. Elwell, Radio Engineer, London. April 24. Attendance 30.

Talks on subjects of current interest in electrical engineering. May 6. Attendance 33.

University of Tennessee

A debate (in cooperation with the Engineering Society) was held on the question *Resolved that the U. S. Government should lease Muscle Shoals to Henry Ford, rather than to the power companies.* (Decided in the negative). February 29. Attendance 59.

Business Meeting. The following Program Committee was appointed: Mr. Fonde, Mr. Woods and Mr. Berry.

Electric Control of Ships and Firing Devices, by J. L. Waller.

The Sperry Gyro-Compass, by Stuart Fonde.

The Advantage to the Student of A. I. E. E. Membership, by Dr. C. A. Perkins. The following officers were elected: President, S. R. Woods; Vice-President, W. B. Sneed; Secretary-Treasurer, W. T. Elliott.

University of Texas

Inspection Trip to the Southwestern Bell Telephone Company Exchange. The visitors were shown through the exchange by Manager Ezelle and the functioning of the various apparatus was explained. March 6. Attendance 20.

The Development of Electrical Engineering from the Beginning to the Present Day, by Professor J. A. Correll. The principal discoveries and the persons responsible for these discoveries in the development of Electrical Engineering were outlined by Professor Correll. The humorous as well as the practical side of the story was very entertainly presented. March 20. Attendance 13.

A motion picture, entitled "The Story of Steel," was shown. Mr. Geo. C. Hengy, student, was elected Chairman to succeed Mr. W. K. Sonnemann. April 10. Attendance 13.

University of Utah

Three-Phase Induction Railway Motors Run from Single-Phase Trolley Lines, by Jos. Lindsey. April 17. Attendance 13.

Virginia Polytechnic Institute

Motion picture, entitled "The Manufacture of an Electric Meter," was shown. April 28. Attendance 145.

Washington University

Problems of the Young Engineer in Adapting Himself to Established Procedure, by E. S. Lee, General Electric Co. Refreshments were served. April 16. Attendance 22.

University of Washington

Annual Banquet. Talks were given by Dean C. E. Magnusson and several of the alumni; stunts and music were furnished by members of the Branch.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers as a cooperative bureau available only to their membership, and maintained by contributions from the societies and their individual members who are directly benefited.

MEN AVAILABLE.—Brief announcements will be published without charge and will not be repeated, except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will, it is hoped, be sufficient, not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case and with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

(*For other employment announcements see page 55 of the Advertising section.*)

POSITIONS OPEN

ELECTRICAL ENGINEER, with ten years' experience in the design and manufacturing of large power induction motors. Must be capable of designing and supervising the manufacture of open slot induction motors in sizes up to 500 h. p. Excellent opportunity for advancement. Give details of experience and salary expected. Location, Indiana. R-3931.

MEN AVAILABLE

ELECTRICAL ENGINEER, technical graduate. Ten years' experience in metering and testing, now foreman of meter test, would like position as superintendent or assistant superin-

tendent of meter department, or would act as general meterman to assist managers in a group of small towns covered by one utility. Desires a location in New York State. Reasonable salary expected. B-7901.

GRADUATE ELECTRICAL ENGINEER, four years' practical experience in design and construction of power plants and substations, special knowledges in relay protection schemes, desires responsible position with public utility company or consulting engineer. 28, married. B-7893.

TECHNICAL GRADUATE, employed. Desires estimating work spare time. Thoroughly experienced in electrical construction and contracting work. Age 26. Vicinity, New York City. B-7929.

ELECTRICAL, MECHANICAL CONSTRUCTION ENGINEER, married. Twenty years' responsible charge of design, construction, operation and maintenance of steam, hydraulic and electric power stations; automatic and manually operated transformer, Edison and railway substations. High tension transmission, net-work and distributing systems, their design and relay protection. Intensive industrial experience in sugar mills, paper mills, coal and gold mining and marine engineering. Five years' machine shop experience. Salary $7000. B-7944.

ENGINEER, MANAGER OR DIVISION MANAGER of an electrical central station public utility in the Pacific Northwest. B-7932.

ELECTRICAL-MECHANICAL ENGINEER, 33, married, technical electrical graduate. Eleven years' experience coal mining, railway and industrial work, available short notice. Capable and responsible to manage a business, a branch sales office, or an engineering and maintenance department. B-7563.

ELECTRICAL ENGINEER, technical graduate now doing distribution engineering for a public utility company, wants to work with company owning chain of plants. Am young and can learn your methods. Want to be associated with chief electrical engineer and grow up with your company. Looking for something permanent and with a future. Healthy, ambitious and industrious. Can go anywhere on fair notice. Would like to hear from you. B-7948.

GRADUATE ELECTRICAL ENGINEER, married, with five years' teaching in electrical engineering and two years' practical experience desires connection with electrical engineering department of a western college preferably. Have taught practically all of the major subjects in this course. Available after June. B-4922.

ENGINEER, 32, E. E., M. E. Three years graduate work. Desires work under successful executive. Six years plant design, construction, development, research. B-1738.

YOUNG ENGINEER, married, desires connection with some company doing electrical installation of either power house, or commercial machinery. Experience covers a period of eight years. Capable of taking complete charge of such work. Location immaterial. B-7960.

ELECTRICAL ENGINEER experienced in electric drive of machine tools, modern shop planning and practise, research, design and manufacture of precision apparatus. B-7833.

ELECTRICAL ENGINEER, age 30, eighteen months' experience on test floor Westinghouse Company, three years chief electrician for industrial firm. Two years wiring and installation motors, generators, etc. Desires position of permanent nature with public utilities or industrial company. B-7940.

ELECTRICAL ENGINEER, technical graduate, Mem. A. I. E. E., open for position. Sixteen years' experience in power plant, substation, distribution lines, transmission lines and street railway operation, maintenance and construction work, including plans and layout. Capable of taking complete charge of work and getting results. B-7942.

ELECTRICAL ENGINEER, technical graduate, married. Twenty years' experience in design, layouts, construction, maintenance and operation of hydro and steam power plants, substations, transmission and distributing systems, street and interurban railways, electric utilities works. Several years manager and chief engineer. Desires position as manager, superintendent or executive electrical engineer. Minimum salary $3600. B-2388.

INSTRUMENT ENGINEER, man with twenty-five years' experience in design of electrical instruments (measuring and signaling) and electro-mechanical apparatus, desires change. Practical as well as technical man. B-7979.

ELECTRICAL ENGINEERING graduate with four years' experience in teaching electrical engineering in a high grade middle western university and one year's experience in steam engineering in the U. S. N. Desires position in operating or distributing department of a flourishing electric utility. Location not of prime importance. B-7598.

PUBLIC UTILITY MANAGER. Position wanted as manager of electric light property in town of 2500 to 5000, or as manager of electric light and water departments. Experienced in engineering and operation departments of large electric companies, with construction company on electric transmission lines and waterworks, one year owner and manager of small electric plant. University training, not a graduate. Age 26, married. Middle west preferred. B-7876.

MAINTENANCE AND CONSTRUCTION ELECTRICIAN desires position. Fully experienced on industrial power and lighting systems, also installation of X-ray, Tungar and Radiotron Equipment. Last position five years. Assoc. A. I. E. E. Good reasons for desiring change. Age 28. B-7988.

SWITCHBOARD SPECIALIST, TRANSMISSION AND DISTRIBUTION ENGINEER. Technical graduate with B. S. and S. M. degrees, single, Associate in A. I. E. E., with over eight years' experience in combined installation, testing, design, research and teaching electrical engineering. Professor of electrical engineering considered. B-7987.

TECHNICAL GRADUATE M. E. I. Westinghouse graduate student course, ten years' experience in the operation and maintenance of power houses and substations and two years with a manufacturing company. Desires to locate with a public utility company. Available on reasonable notice. B-3645.

PROFESSOR OF ELECTRICAL ENGINEERING in a strong state university desires a change only to secure executive responsibility and increased income. Age 39, health excellent, married. Member of honorary societies. The best of collegiate and technical training. Valuable construction, consulting experience as well as several years in present position. B-7925.

TECHNICAL COLLEGE GRADUATE in E. E. Age 27. Experience G. E. test and distribution work with large power and light company of eastern Massachusetts. Desires position in electrical engineering department of power and light company in distribution or station work. B-8007.

PATENT ATTORNEY, mechanical and electrical engineer with designing and manufacturing experience, desires additional work or connection with a manufacturing or engineering organization. B-6941.

PUBLIC UTILITY EXECUTIVE, electrical and mechanical engineer, long and exceptionally broad experience, not only in construction and operation of electric and gas properties but organization, management, financing, and consolidation; capable of taking entire charge of large utility or group of properties, excellent financing connections. B-8020.

PROFESSOR OF ELECTRICAL ENGINEERING, age 39. B. S. and E. E. degrees from first class institutions. Manufacturing, construction, teaching and research experience. Salary $3600. B-8012.

EXECUTIVE ENGINEER, good organizer, desires position with growing commercial company, experience has covered manufacturing, appraisal, maintenance and power plant operation, rehabilitation of old and inefficient plants, organizing branch factories. Good initiative and ability, excellent references. Eight years with large automobile industry. Available on reasonable notice, at present located in Canada. B-8011.

ELECTRICAL MECHANICAL ENGINEER, graduate of Turin's Polytechnic University (Italy), age 28, single. Initiative and inventive ability, with some patents in electrical apparatus, good draftsman, laboratory experience, desires position with reliable concern. Knowledge of French, Italian and enough English. Willing to start from manual work if necessary. Anywhere, New York preferable. B-7208.

YOUNG MAN, 24, graduated in May 1924 from an evening course in electrical engineering. Five years' experience in mechanical drafting, checking and inspecting. Would start from the bottom on anything electrical in New York City. Available in one week. B-7270.

ELECTRICAL ENGINEER, 35, single, now employed. Experience on design, construction and sales engineering work on power stations, substations, transmission lines, distribution, industrial drives, in this country and in Europe. Also interested in administration and business, soon finishing Alexander Hamilton Institute course. Knows four important foreign languages. B-7977.

TECHNICAL GRADUATE, 4 years' experience, substation layout, A-C. motor design, six months' electrical testing, extensive traveling experience, speaking fluently five European languages. Desires sales experience along electrical lines (foreign sales preferred), or electric transmission line construction and operation experience. Efficient worker, excellent record. Available after July 1st. B-8043.

RECENT GRADUATE, B. S. in E. E. No engineering experience but shop practise in several large operating and manufacturing companies (summer positions.) Available after June 2nd, 1924. New York City location preferred. B-8060.

ELECTRICAL ENGINEERING GRADUATE, age 25, sixteen months on General Electric Test and one year of engineering and commercial work. Desires position with public utility. Only position having steady work and chance for advancement will be considered. B-8040.

GRADUATE B. S. in E. E. 1923, age 24, speaking English and Spanish, desires position with firm designing and constructing power plants and factory, mine and lighting systems. Experience obtained while attending college; meter calibration and testing, motor repairing, shop work. Good opportunity for a concern dealing with Latin American countries to use services of an ambitious young man familiar with American and Latin ways and who will do his best to prove efficient. B-8046.

GRADUATE ELECTRICAL ENGINEER, single, age 26, desires position with some small concern manufacturing radio or electrical equipment. One year graduate work in electrical engineering, two years research and design of communication apparatus. Location immaterial. B-8042.

MECHANICAL AND ELECTRICAL ENGINEER, American, desires responsible position. Twenty years' experience in construction, operation and maintenance of power plants and street railways. Working knowledge of Spanish, excellent references. Now employed, available short notice. B-6459.

GRADUATE MECHANICAL-ELECTRICAL ENGINEER, twenty years' experience. Desires connection with power or industrial company or with engineering firm. Six years' installation work and later district engineer large electrical manufacturer. Wide experience industrial ap-

plications. Three years power department large paper manufacturer. Familiar operation and maintenance steam electric stations and boiler houses. B-6764.

ELECTRICAL ENGINEER, age 24, graduate with B. S. (1922) and M. S. (1924). Member of Tau Beta Pi. Two years' experience teaching in electrical engineering department of a college. Desires position as instructor in physics or electrical engineering department of a college. B-7986.

GRADUATE MECHANICAL-ELECTRICAL ENGINEER, well grounded in fundamentals and theory and reinforced with broad practical experience covering development, design, manufacturing and construction of engineering properties and equipment. Also plans, specifications, purchase, installation and operation of mechanical, electrical, hydraulic and refrigerating plants and equipment. Desires responsible position of consultative or advisory capacity with aggressive manufacturing power or engineering concern. B-2656.

ELECTRICAL ENGINEER, technical graduate, married, 32. Ten years' experience with system which has grown from 1200 to 30000 K. W. Will locate anywhere in northern U.S. Prefer town less than 150,000. Now engaged. Location manager or superintendent, electrical engineer, distribution engineer, street lighting. Minimum salary $3600. B-8058.

ELECTRICAL ENGINEERING GRADUATE, 25. Have had experience in appraisal of public utility electrical equipment after having had a year's experience in construction, both generating and substation. Also knowledge of public utility accounting. Location New York City or vicinity. Available within a week. B-4997.

ELECTRICAL ENGINEERING GRADUATE, 30, with five years' teaching experience and two years' general engineering work desires position wth construction or operating department of electric utility company, or assistant professorship in electrical engineering department of a college or university. B-8064.

ELECTRICAL GRADUATE, age 25, three years' experience, desires permanent connection with a public utility or contracting company in electrical construction, maintenance or operating departments, leading to an executive position. Location, Eastern states. B-8056.

MECHANICAL-ELECTRICAL ENGINEER, 32. Fifteen years power house and substation construction, transformation and repairs. Six years service engineer in field; rebuilding and rewinding of larger size turbo generators, rotary commutators, transformers, etc. One year railway subway experience with 3000 D. C. on Chicago and Milwaukee electrification in Montana. Responsible charge, opportunity for advancement desired. B-8055.

ELECTRICAL ENGINEER, B. S. in E. E., three years' experience in construction of H. T. outdoor substations and power plant, one year G. E. Test and some drafting, desires position in design or construction. B-4970.

YOUNG MAN, 26, single, seeks connection with organization offering promise of a career. Has E. E. degree and post graduate work in physics. Has experience in teaching, research and manufacturing. At present employed in manufacturing concern but change is desired. Available on short notice. Will locate anywhere. B-3411.

GRADUATE ELECTRICAL ENGINEER with broad education, knowledge of foreign languages. Ten years' experience. Testfloor, commercial experience in central station equipment, design of switchboards and relay applications. Desires permanent connection with growing concern with opportunity for advancement. B-8068.

RECENT GRADUATE of Norwich University, B. S. in E. E. Student member A. I. E. E. Has no practical experience, desires position with opportunity to advance. Location in New England or New York preferred. B-8066.

EXECUTIVE ENGINEER of high standing and having particularly wide experience both in America and Europe. Activities have included several years' practise as consulting engineer in the design and operation of hydro-electric plants and high tension transmission systems and six years as chief engineer of a prominent electrical utility, operating principally at 110 kv. Available on reasonably short notice. B-8069.

ELECTRICAL ENGINEER, technical graduate. Seventeen years' experience in electrical control manufacture and sales, industrial operation, engineering and research. Desires to locate with an electrical manufacturer, either in production or sales engineering, or with a consulting engineer or firm of established reputation. Only a permanent proposition considered. Location preferred, Philadelphia or New England. B-6694.

INSTRUCTOR 1924, graduate Electrical Engineer with radio and telephone experience. B-8062.

ENGINEER, E. E., M. E. Graduate work Ch. E. Served apprenticeship foundry, machine shop and assembly; test design, cost, departments manufacturer electrical, also refrigerating, equipment. Year development work. Five years responsible charge plant design, construction, maintenance, paint and chemical plants. Desires non-chemical work under successful executive in progressive concern, or firm consulting engineers. B-1738.

ENGINEER, 30, eight years out. Purchasing, specification, development, appraisal, tests, with industrial and public utility companies, desired connection would be with public utility management concern along substation and central power lines. B-6944.

ELECTRICAL ENGINEERING GRADUATE, 35, married. Eight years' practical experience and two years teaching since graduation. Want public utilities or work in electrical department of jobber of electrical power machinery. Employed now. Must give thirty days' notice. Prefer west or middle west. Perfect health, best references. Associate A. I. E. E. B-8099.

ELECTRICAL ENGINEER-EXECUTIVE, experience covers large construction and management work in public utility and factory management. Successful in economical administration, eliminating useless overhead and manufacturing waste, and obtaining profitable results. Can take full charge of large operation. B-7919.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED MAY 16, 1924

*ADAMS, JOHN ALBAN, Student Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.

ALLEN V., CARLOS, Chief Electrician, Mexican Corporation, S. A., Fresnillo, Zac., Mex.

AUXER, FRED P., President, The National Telephone Supply Co., 5100 Superior Ave., Cleveland. Ohio.

BARRERE, MAURICE, Engineer, M. M. Schneider & Co., 42 Rue d' Anzon, Paris, France.

BEAULIEU, LEO E., Student Engineer, General Electric Co., Lynn; res., Holyoke, Mass.

BECKWITH, GEORGE S., Asst. Engineer, New York Telephone Co., 104 Broad St., New York; res., Brooklyn, N. Y.

BERRY, JOHN BROADUS, Supervisor, Transmission Maintenance, Cumberland Tel. & Tel. Co., Nashville, Tenn.

BEUTLER, ERNEST CHARLES, Meter Tester, New York Edison Co., New York, N. Y.; res., Bogota, N. J.

BONN, FREDRICK GOTTLIEB, Electrical Engineer, Hammond Cedar Co., Ltd., Port Hammond; res., Hammond, B. C.

BREDAHL, AXEL CARL, Draftsman, C. M. S., Inc., 38 White St., Tarrytown; res., Yonkers, N. Y.

BRENT, DERELL J., Assistant, Engg. Dept., West Penn Power Co., 14 Wood St., Pittsburgh, Pa.

BUYS, IVAN, Superintendent of Transmission, Kansas Gas & Electric Co., Wichita, Kans.

CADY, JOHN JOSEPH, Electrician, 65 W. 3rd St., South Boston, Mass.

*CAMPBELL, COLIN C., Pacific Gas & Electric Co., 445 Sutter St., San Francisco; for mail, Berkeley, Calif.

CARR, JOHN LILBURN, Commercial Dept., General Electric Co., Commercial National Bank Bldg., Washington, D. C.

CARROLL, HUGH A., Student Engineer, General Electric Co., Lynn; res., West Lynn, Mass.

CHAPMAN, HARRY EDISON, Field Engineer, Southern New England Telephone Co., 185 Pearl St., Hartford; res., Burnside, Conn.

CHRISTMAN, CHARLES W., Inspector, Brooklyn Edison Co., 561 Grand Ave., Brooklyn; res., New York, N. Y.

*COCHRAN, ROBERT DICKSON, Local Manager, Iowa Light, Heat & Power Co., Orange City; res., Alton, Iowa.

*COOK, THOMAS JAMES, Technical Employee, American Tel. & Tel. Co., Hurt Bldg., Atlanta, Ga.

CRANE, ARTHUR SEYMOUR, Power Representative, Public Service Electric Co., 80 Park Pl., Newark, N. J.; res., New York, N. Y.

*DANNER, EARL YOUNG, Student, University of Washington, 6321-10th Ave., N. E., Seattle, Wash.

DECKER, CHARLES R., Engineer, Hudson Coal Co., 434 Wyoming Ave., Scranton, Pa.

DENROCHE, WILFRED EARL, Manager, Wagner Electric Co. of Canada, Ltd., 215 Dundas St., E., Toronto, Ont., Can.

DUSINBERRE, HENRY WARNER, Ensign, U. S. Navy, Asst. Radio Officer, U. S. S. Arkansas, New York, N. Y.

ENGEL, THEODORE JOSEPH, Junior Electrical Engineer, Western Electric Co., Inc., 463 West St., New York; res., Woodside, N. Y.

EVANS, ALFRED JOHN, Electrical Draughtsman, New York Edison Co., 44 E. 23rd St., New York, N. Y.

*EWING, ROSS, Salesman, Westinghouse Elec. & Mfg. Co., 1535-6th St., Detroit, Mich.

FERRO, DANIEL EDWARD, Electrician, Stevens & Wood, 120 Broadway, New York, N. Y.; res., Newark, N. J.

FINNICUM, JOHN LYLE, Power Apparatus Specialist, Western Electric Co., Inc., Water & West Sts., Pittsburgh, Pa.

FLETCHER, ELMER LEE, Asst. Engineer, New York Telephone Co., 104 Broad St., New York, N. Y.
FOWLER, WARREN HENRY, P. B. X. Dept., Illinois Bell Telephone Co., Chicago, Ill.
*FRY, LLOYD CHARLES, Student Engineer, River Works, General Electric Co., Lynn, Mass.
GERGE, NILS EINAR GEORGIE, Royal Swedish Legation, Calle de Liverpool No. 5, Mexico, D. F., Mex.
GERKEN, JOHN H., Superintendent of Electric Construction, Robert E. Denike, Inc., 155 E. 33rd St., New York, N. Y.
GRADY, EDWARD A., Division Plant Engineer, Ohio Bell Telephone Co., 104 N. Third St., Columbus, Ohio.
*GRAY, ROBERT, Cable Tester, Bell Telephone Co. of Canada, 33 Temperance St., Toronto, Ont., Can.
GREIF, JOHN HENRY, Asst. Chief Inspector, Manhattan Electric Supply Co., 45 Morris St., Jersey City; res., Guttenburg, N. J.
GRIFFING, RALPH A., President & Manager, Harlem Valley Electric Corp., Pawling, N. Y.. res., Danbury, Conn.
GROSS, CARL GEORGE, Engineer, Eastern Laboratory, Inc., 229 E. 38th St., New York, N. Y.
HALSEY, FORDYCE COOK, Dynamo Tender & Shift Engineer, Radio Corp. of America, Port Jefferson, N. Y.
HARRIS, LEONARD F., Telephone Engineer, New York Telephone Co., 104 Broad St., New York; res., Brooklyn, N. Y.
*HATFIELD, HOMER F., Test Engineer, Harwood Plant, Pennsylvania Power & Light Co., Harwood Mines, Pa.
HEGAZY, HAMED MAHMOND, Egyptian Public Works Ministry, 54 Coniston Road, Muswell Hill N. 10, London, Eng.
HEINRICH, HERBERT WILLIAM, Engineer, Travelers Insurance Co., 700 Main St., Hartford, Conn.
HENRY, RAYMOND T., Asst. Electrical Engineer, The Niagara Falls Power Co., Niagara Falls, N. Y
HERR, EDWIN DEAN, Foreman, Pennsylvania Railroad Co., Sunnyside Engine House, Long Island City, N. Y.; res., Newark, N. J.
HERRLEY, BENJAMIN G., Instructor in Electric Wiring, The College of the City of New York, 23rd St. & Lexington Ave., New York; res., Brooklyn, N. Y.
HICKSON, JULIAN I., Layout Work, H. J. C. Pearson, 101 Marietta Bldg., Atlanta, Ga.
HOKANSON, CARL LUDWIG, Designer, Dwight P. Robinson & Co., Inc., 125 E. 46th St., New York, N. Y.
HOPPER, ELLSWORTH STEVEN, Chief Operator, Braden Copper Co., Rancagua, Chile, So. Amer.
HULLEY, LEVI WOODBURY, Asst. Engineer, New York Telephone Co., 15 Dey St., New York; res., New Brighton, N. Y
JAMES, LUTHER H., Asst. Electrical Engineer, Hudson Coal Co., 434 Wyoming Ave., Scranton, Pa.
JENSEN, BOERGE OTTO HENRIK, Electrical Tester, Westinghouse Elec. & Mfg. Co., Newark; res., Arlington, N. J.
JONES, ARTHUR E., President, Irvington Varnish & Insulator Co., Irvington, N. J.
KIPP, KARL, 147 E. 150th St., New York, N. Y.
KRAMER, ALEXANDER E., Electrical Draftsman, Thomas E. Murray, Inc., 55 Duane St., New York; res., Brooklyn, N. Y.
LEAVITT, LOUIS SELWIN, Electrical Engineer, The Lowell Electric Light Corp., Lowell, Mass.
*LOTHROP, ESMOND FREEMAN, Turbine Tester, General Electric Co., Lynn; res., Saugus, Mass.
MacWHINNIE, DONALD T., Student, Machine & Switching School, New York Telephone Co., New York; res., Jamaica, N. Y.
MANHARTSBERGER, NORBERT, 23 Halsey St., Brooklyn, N. Y.
MARTIN, FITZHUGH LEE, Switchboard Operator, Cheswick; res., Oakmont, Pa.
MASON, HARRY H., Electrician, Atlantic City Electric Co., Atlantic City, N. J.
MATTHEWSON, FRANK, Test Engineer, Southland Hydro-Electric Power Board, Invercargill, New Zealand.
*MAXWELL, GEORGE WILLIAM, Radio Expert & Tester, American Radio & Research Corp., Medford Hillside; res., Melrose, Mass.
MAYER, VERNON WILLIAM, Draftsman, General Electric Co., 1900 Washington Blvd., Baltimore, Md.
McAVOY, WILLIAM HENRY, Electrical Draftsman, Dwight P. Robinson & Co., 125 E. 46th St., New York, N. Y.
*MEARS, CLARKE BRAIDWOOD, Electrical Construction Dept., Philadelphia Electric Co., 25th & Christian Sts., Philadelphia, Pa.; res., Collingswood, N. J.
*METZGER, HERMAN ARTHUR, Engineer, Andian National Corp., Ltd., Apartado 130, Cartagena, Colombia, So. Amer.
MEYER, CARL A., Switchboard & Control Design, Sargent & Lundy, 72 W. Adams St., Chicago, Ill.
*MILLEA, LEO, Electric Transportation Trucks Maintenance, Worcester, Mass.
MOTT, FRANK S., Sales Engineer, Goodman Mfg. Co., 4834 S. Halsted St., Chicago, Ill.
NELSON, ARTHUR EMIL, Asst. Engineer, New York Telephone Co., 104 Broad St., New York; res., White Plains, N. Y.
NOLAN, CLARENCE ELMER, Service Engineer, The Bristol Co., Waterbury; for mail, Naugatuck, Conn.
NORDLIEN, BERGER W., Tester, Westinghouse Elec. & Mfg. Co., East Pittsburgh; for mail, Wilkinsburg, Pa.
*NORDLIN, HENRY WILLIAM, Inspector, Western Electric Co., Inc., Winchendon, Mass.
OWENS, LEONIDAS HOWARD, 3542 N. 23rd St., Philadelphia, Pa.
PEARSON, DONALD MABRY, Engineer, Pacific Tel. & Tel. Co., 835 Howard St., San Francisco, Calif.
PIERSON, WILLIAM HENRY, Asst. Engineer, New York Telephone Co., 104 Broad St., New York, N. Y.
PLAISTED, GUY EDGAR, Electrical Design Engineer, D. C. Motor Engg. Dept., General Electric Co., Schenectady, N. Y.
*POKORNY, JEROME JOHN, Switchboard Dept., Westinghouse Elec. & Mfg. Co., 2209 Ashland Rd., Cleveland, Ohio.
POWERS, RALPH ALDEN, Electrical Engineer, Meter & Instrument Engg. Dept., General Electric Co., West Lynn; res., East Lynn, Mass.
PYE, HAROLD CHARLES, Research Engineer, Automatic Electric Co., 1023 W. Van Buren St., Chicago; res., Oak Park, Ill.
RADCLIFFE, THOMAS JULIAN, Research Assistant, Edison Lamp Works of General Electric Co., Harrison; res., Belleville, N. J.
RALL, ALBERT A., Manager, Service Dept., Kansas City Power & Light Co., 1330 Grand Ave., Kansas City; res., Independence, Mo.
RAYNOR, HARRISON STRONG, Asst. Engineer, New York Telephone Co., 104 Broad St., New York, N. Y.
*REARDEN, JAMES ROBERT, Supervisor of Transmission Maintenance, Southern Bell Tel. & Tel. Co., Jacksonville, Fla.
REICHEL, WLADIMIR ALEXANDROVITCH, Electrical Designer, Public Service Production Corp. of New Jersey, Newark, N. J.
ROBINSON, CARL E., Chief Electrician, Standard Steel Works Co., Burnham; res., Lewiston, Pa.
ROSKELLEY, CHARLES O., Engineer, First National Bank, Brigham, Utah.
*SANDS, JOHN W., Research Assistant, International Nickel Co., Bayonne, N. J.
SANTUARI, EMILIO, Electrical Engineer, Societa Generale Elettrica Tridentina, via Stazione 7, Bolzano, Alto Adige, Italy.
SCHNAPP, MICHAEL HERBERT, Sales Engineer, General Electric Co., 809 Rialto Bldg., San Francisco, Calif.
*SCHRODER, JOHN HENRY, Engineering Assistant, Public Service Production Co., 80 Park Pl., Newark, N. J.
SCHUBERT, HYMEN, Foreman, Philadelphia Electric Co., Somerset & Trenton Aves., Philadelphia, Pa.
SCHUHMANN, WILLIAM JOHN, Sales Engineer, Roller-Smith Co., 2136 Woolworth Bldg., New York, N. Y.
*SCOTT, HORACE S., Asst. District Manager, Kentucky & West Virginia Power Co., Sprigg, W. Va.
SEN, RANJIT CHANDRA, Student Engineer, General Electric Co., West Lynn, Mass.
SINGER, JOHN IRVINE, Chief Operator, Ohio Public Service Co., 526 E. Main St., Alliance, Ohio.
SMALLEY, OSCAR DUANE, Instructor, Electrical Engineering Dept., Iowa State College, Ames, Iowa.
*SMITH, ALFRED M., Substation Operator, Kansas City Power & Light Co., 1330 Grand Ave., Kansas City, Mo.
SMITH, JOHN BRUCE, Representative in Mexico, W. T. Henley's Telegraph Works Co., Ltd., 5 de Mayo No. 1 B, Mexico City, Mex.
SNOWDEN, JOHN WILLIAM, Jr., Asst. Engineer, New York Telephone Co., 104 Broad St., New York; res., Peekskill, N. Y.
*SOMERS, FREDERICK WILLIAM, Electrical Engineer, Cline Electrical Mfg. Co., Fisher Bldg., Chicago, Ill.
SORENSEN, ANDREW C., Electrical Engineer, New York Telephone Co., 104 Broad St., New York; res., Brooklyn, N. Y.
STEGEMAN, G. A., Jr., System Operator, Metropolitan Edison Co., Reading, Pa.
STEINBACH, HERMAN L., Engineer, Westinghouse Elec. & Mfg. Co., 1255 W. 4th St., Cleveland, Ohio.
SUTHERLAND, ROBERT ALEXANDER, Junior Engineer, Elec. Pr. & Lt. Dept., Dunedin City Corp., 21 Sheen St., Dunedin, New Zealand.
SYCHRA, SVATOPLUK, Engineer, Engg. Dept., Ceskomoravska-Kolben Co., Prague-Vysocany, Czechoslovakia.
TATES, HARRY W., Union Electric Construction Co., 282 Madison St., New York, N. Y.
THAYER, RUSSELL J., Test Engineer, Equipment Div., Willard Storage Battery Co., E. 131st St., Cleveland; res., East Cleveland, Ohio.
THIEDEMANN, THOMAS, Assistant, Electrical Dept., Havana Electric Railway, Light & Power Co., Monte No. 1, Havana, Cuba.
*THOMAS, EARL E., Electrical Engineer, Industrial Engg. Dept., General Electric Co., Schenectady, N. Y.
UHL, HARRY C., Industrial Engineering Dept., General Electric Co., Schenectady, N. Y.
VAN AUKEN, RALPH STRAWWAY, Asst. Foreman Electrical Maintenance, General Electric Co., Ft. Wayne, Ind.
VELANDER, STEN, Consulting Engineer, Power Company of South Sweden, Malmo, Sweden.
WERNER, WILBUR STANLEY, Electrical Engineer, The Kelley-Koett Mfg. Co., 214 W. 4th St., Covington, Ky.
*WICHMAN, MARTIN FREDRICK, Interference Engineer, Northwestern Bell Telephone Co., 420-3rd Ave., S., Minneapolis, Minn.
WORLEY, JOSEPH, Instructor, Elec. Engg. Dept., Missouri School of Mines & Metallurgy, Rolla, Mo.; for mail, Noblesville, Ind.
WURZBACH, H. E., Chief Electrician, Magna Plant, Utah Copper Co., Magna, Utah.

Total 120

*Formerly Enrolled Students

ASSOCIATES REELECTED MAY 16, 1924.

CAMPBELL, EDGAR EVERETT, Engineer, Service Investigations, Commonwealth Edison Co., Edison Bldg., Chicago, Ill.
FUNDAMANT, WALLACE, Warminskiego Str. 9, Bydgoszcz, Poland
GILMAN, EDWARD FRANCIS, Electrician, Wood Worsted Mill, Lawrence, Mass.
MONTGOMERY, MARTIN, District Engineer, Canadian Westinghouse Co., Ltd., Vancouver, B. C., Can.
REYNOLDS, HERBERT BYRON, Mechanical Research Engineer, Motive Power Dept., Interborough Rapid Transit Co., 600 W. 59th St., New York, N. Y.
SANDIG, GEORGE CURT, Laboratory Tester, Public Service Co. of Colorado, 2145 Blake St., Denver, Colo.
WOODWARD, CHARLES V., Manager, Westinghouse Elec. & Mfg. Co., 121 E. Baltimore St., Baltimore, Md.

MEMBERS ELECTED MAY 16, 1924.

AVERY, MORTON BROWN, Asst. Chief Engineer, Rochester & Syracuse Railroad Co. and Empire State Railroad Corp., Newark, N. Y.
EILER, ERNEST EARL, Capt. U. S. M. C., Force Signal Officer, Signal Battalion, Marine Barracks, Quantico, Va.
MORRISSEY, JOHN P., President, John P. Morrissey, Inc., 17 E. 42nd St., New York, N. Y.
PHILLIPS, NATHANIEL DAVID B., Asst. to Canadian Manager, Ferguson-Pailin Co., Ltd., 321 King St., E., Toronto, Ont., Can.

TRANSFERRED TO GRADE OF FELLOW MAY 16, 1924.

BUSH, VANNEVAR, Professor of Electric Power Transmission, Massachusetts Institute of Technology, Cambridge, Mass.
TIMBIE, WILLIAM H., Professor of Electrical Engineering & Industrial Practise, Massachusetts Institute of Technology, Cambridge, Mass.

TRANSFERRED TO GRADE OF MEMBER MAY 16, 1924.

ALDER, GEORGE W., Consulting Engineer, Good Housekeeping Institute, New York, N. Y.
BEAN, LESLIE P. R., Electrical Engineer, Sydney, Australia.
BETTIS, ALEXANDER E., Superintendent Engineering & Construction, Kansas City Power & Light Co., Kansas City, Mo.
DE CAMP, SAMUEL M., Local Engineer, General Electric Co., Kansas City, Mo.
MEHARG, LAURENCE, Chief Engineer, Hazel-Atlas Glass Co., Wheeling, W. Va.
OLSEN, EDWARD A., Superintendent of Operation, Alexandria Light & Power Co., Alexandria, Va.
RETT, CARL E., Chief Engineer, Lambert Tire & Rubber Co., Barberton, Ohio.
RICHARDS, KEENE, Industrial Engineer, Detroit, Mich.
SCHAEFER, CLARENCE C., Traffic Engineer-Operation, Philadelphia Rapid Transit Co., Philadelphia, Pa.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held May 12, 1924, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Member

GIBBS, CLARENCE D., Dwight P. Robinson & Co., New York.
MACKLER, LOUIS, Leading Electrical Draftsman, New York Edison Co., New York.
MAHAN, JAMES S., Electrical & Fire Prevention Inspector, Western Actuarial Bureau, Chicago, Ill.
McELROY, GEORGE, Manager, Bridgeport Office, Westinghouse Electric & Mfg. Co., Bridgeport, Conn.
MONTSINGER, VINCENT M., Consulting & Research Engineer, General Electric Co., Pittsfield, Mass.
TAYLOR, CHARLES H., Chief Communications Engineer, Radio Corporation of America, New York.
THOMSON, GEORGE L. A., Electrical Division Chief, Testing Laboratory, Public Service Electric Co., Irvington, N. J.
WOOLSTON, LOUIS F. B., Engineer, General Electric Co., St. Louis, Mo.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before June 30, 1924.

Adams, E. L., Kerite Insulated Wire & Cable Co., Chicago, Ill.
Anderson, W., General Electric Co., Pittsburgh, Pa.
Asklund, A. E. I., Houston Lighting & Power Co., Houston, Texas.
Baker, W. R., New York Telephone Co., New York, N. Y.
Barnes, H. F., New York Telephone Co., Newark, N. J.
Barr, O., West Penn Power Co., Pittsburgh, Pa.
Bergstrom, M. B., J. E. Sumpter Co., Minneapolis, Minn.
Boekenoogen, E. V., So. California Edison Co., Los Angeles, Calif.
Bohmfeldt, R. R., Jr., Sperry Gyroscope Co., Brooklyn, N. Y.
Bollenbacher, E. H., McClellen & Junkersfeld, St. Louis, Mo.
Braisted, Le Roy, with C. E. Wise, Detroit, Mich.
Brooks, A. F., The So. New England Telephone Co., New Haven, Conn.
Brust, R. S., The So. New England Telephone Co., New Haven, Conn.
Burton, J. A., Jr., American Tel. & Tel. Co., New York, N. Y.
Bushnell, W. LeR., Westinghouse Elec. & Mfg. Co., New York, N. Y.
Buzby, A. D., Wellman-Seaver-Morgan Co., New York, N. Y.
Carroll, F. J., The Pacific Tel. & Tel. Co., Seattle, Wash.
Carroll, J. S., Graduate Student, Stanford University, Calif.
Clary, H. L., Radio Engineer, 3030 Wells St., Milwaukee, Wis.
Cleeland, W. J., New York Telephone Co., Newark, N. J.
Conroy, E. W., Puget Sound Power & Light Co., Tacoma, Wash.
Cooper, N. L., Electrician, Navy Yard, Washington, D. C.
Cory, S. I., American Tel. & Tel. Co., New York, N. Y.
Darling, G. F., Manufacturer's Representative, Electrical Lines, Minneapolis, Minn. (Applicant for re-election)
Davidson, C. J., American Tel. & Tel. Co., New York, N. Y.
del Corral, M., (Member), Vicente B. Villa & Co., New York, N. Y.
Desaix, H. W., Watson-Flagg Engineering Co., Paterson, N. J.
Dixon, J., Puget Sound Power & Light Co., Tacoma, Wash.
Donaghey, C. E., Duquesne Light Co., Pittsburgh, Pa.
Drake, E. F., Puget Sound Power & Light Co., Tacoma, Wash.
Drake, L. M., Scientific Research Lab., L. M. Drake, Daytona, Fla.
Driscoll, W. B., Public Service Co., St. Paul, Minn.
Ehrenfeld, R., (Member), Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Erickson, J. R., General Electric Co., Erie, Pa.
Fingerhart, J., New York Edison Co., New York, N. Y.
Fiske, H. C., J. E. Sumpter Co., Minneapolis, Minn.
Flader, F. M., Duquesne Light Co., Pittsburgh, Pa.
Fleckenstein, C. A., Public Service Electric Co., Irvington, N. J.
Fong, W. B., Pacific Gas & Electric Co., San Francisco, Calif.
Gaskill, E. M., Brooklyn Edison Co., Brooklyn, N. Y.
Gaskins, R. W., Stone & Webster, Inc., Boston, Mass.
Gibson, C. H., Maine Central Railroad, Fairfield, Maine.
Goble, J. C., Public Service Production Co., Trenton, N. J.
Gochicoa, E. R., General Electric Co., Erie, Pa.
Goldsmith, E. L., (Member), Attorney-at-Law, Indianapolis, Ind.
Gorton, R. E., Tech. Lab. Asst., Stevens Inst. of Tech., Hoboken, N. J.
Graff, P. T., Okonite Co., Passaic, N. J.
Gray, W. R., (Member), The Eppley Laboratory, Newport, R. I.
Greene, F. M., Eisemann Magneto Corp., Brooklyn, N. Y.
Halvorsen, E. H., The Winchester Radio Co., Boston, Mass.
Hamilton, H. S., (Member), American Tel. & Tel. Co., New York, N. Y.
Hamm, E. I., Western Electric Co., Inc., New York, N. Y.
Hemmander, K. A. D., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Herrmann, A. M., New York Telephone Co., Brooklyn, N. Y.
Hilliard, G. D., Public Service Co., Trenton, N. J.
Hocker, M. J., Public Service Production Co., Newark, N. J.
Hollowell, G. A., General Electric Co., Schenectady, N. Y.
Horter, B. M., Cutler-Hammer Mfg. Co., Wilkes-Barre, Pa.
Jacobs, O. B., American Tel. & Tel. Co., New York, N. Y.
Jennings, R. S., Utah Power & Light Co., Salt Lake City, Utah
Johnson, A. C., Postal Telegraph-Cable Co., New York, N. Y.
Johnson, G. E., The New York Edison Co., New York, N. Y.
Johnson, J. A., (Member), Kuhlman Electric Co., Bay City, Mich.
Johnson, K. H., Western Electric Co., Inc., New York, N. Y.
Jones, G. W., Public Service Electric Co., Trenton, N. J.
Keller, W. T., Stone & Webster, Inc., Boston, Mass.
Kerr, T. B., Brooklyn Edison Co., Brooklyn, N. Y.
Khasan, L. A., Elec. Draftsman, 2109 Harrison Ave., New York, N. Y.
Koch, W. A., Jr., U. G. I. Contracting Co., Philadelphia, Pa.
Kvamme, I. F., Duquesne Light Co., Manchester, Pa.
Lantz, C. R., Tacoma Dredging Co., Tacoma, Wash.
Lawrence, O. U., Research Corp., Bound Brook, N. J.
Lechler, W. L., Electric Storage Battery Co., Philadelphia, Pa.
Leland, G. H., (Member), The Leland Electric Co., Dayton, Ohio

Leonard, S. G., (Member), The Cleveland Railway Co., Cleveland, Ohio
Lindberg, W. A., Commonwealth Edison Co., Chicago, Ill.
Lindner, Charles P., New York Telephone Co., Newark, N. J.
Lyons, N. D., (Member), New York Central Railroad, New York, N. Y.
Masten, L. B., New York Telephone Co., Newark, N. J.
Mathieu, H. P., American Bridge Co., Ambridge, Pa.
McBane, L. J., Case School of Applied Science, Cleveland, Ohio
McGill, J. H., (Member), Narragansett Elec. Lighting Co., Providence, R. I.
McLaren, G. S., Canadian Westinghouse Co., Hamilton, Ont., Can.
Mead, E. F., Westinghouse Elec. & Mfg. Co., Baltimore, Md.
Meany, R. A., New York Telephone Co., Brooklyn, N. Y.
Melhuish, L. E., Western Electric Co., Inc., New York, N. Y.
Millard, J. B., Hartford Electric Light Co., Hartford, Conn.
Miller, F. J., Public Service Production Co., Trenton, N. J.
Miller, M., Club Auto Renting Service, New York, N. Y.
Milling, J. C., General Electric Co., Erie, Pa.
Morrison, J., Public Service Production Co., Trenton, N. J.
Neumann, A. C., Public Service Production Co., Trenton, N. J.
Nicholls, S. W., West Penn Power Co., Pittsburgh, Pa.
Novak, J. J., Illinois Bell Telephone Co., Chicago, Ill.
Oman, C., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Orcutt, F. A., N. Y. N. H. & H. R. R., Stamford, Conn.
Ott, W. N., Public Service Production Co., Newark, N. J.
Oswald, C. M. Westinghouse Elec. & Mfg. Co., Philadelphia, Pa.
Paolini, M., N. Y. & Q. E. L. & P. Co., Flushing, N. Y.
Paul, P. J., Weston Dodson & Co., Inc., Shenandoah, Pa.
Pazin, J. C., Duquesne Light Co., Pittsburgh, Pa.
Peterson, R. S., Commonwealth Edison Co., Chicago, Ill.
Portis, R. J., Asst. Engr., City National Bank Blvd., Long Beach, Calif.
Potts, W. F., (Member), Rumsey Electric Co., Philadelphia, Pa.
Raab, J. H., Westchester Lighting Co., Mt. Vernon, N. Y.
Raznik, E. E., American Tel. & Tel. Co., Morristown, N. J.
Reeves, G. S., University of Wyoming, Laramie, Wyo.
Rigler, H. M., Portland Electric Power Co., Portland, Ore.
Rippel, K. W., Bethlehem Steel Co., Sparrows Point, Md.
Robinson, H. A., Duquesne Light Co., Pittsburgh, Pa.
Runciman, A. S., Shawinigan Water & Power Co., Montreal, Que., Can.
Sanborn, A. P., (Member), Eastern Cuba Sugar Corp., Central Violeta, Prov. de'Camaguey, Cuba.
Satler, R. L., West Penn Power Co., Pittsburgh, Pa.
Schiller, H. J., Brooklyn Edison Co., Inc., Brooklyn, N. Y.
Schillin, C. A., New Orleans Public Service, Inc. New Orleans, La.
Shadgett, L. M., Alabama Power Co., Birmingham, Ala.
Shipp, R. L., (Member), Guanajuato Pr. & Elec. Co., Guanajuato, Mex.
Shoffstall, H. F., American Tel. & Tel. Co., New York, N. Y.
Simmons, G. H., Automatic Electric Co., Chicago, Ill.
Slack, E. P., (Member), Underwriter's Laboratories, New York, N. Y.
Slocum, S. E., New York Telephone Co., New York, N. Y.
Smedley, A. B., Cooper Hewett Electric Co., Cincinnati, Ohio
Strike, C. J., Consumers Electric Co., Webster, S. D.
Sudlow, H., The Carolina Light & Power Co., Aiken, S. C. (Applicant for re-election)
Swan, R. H., New York Telephone Co., Newark, N. J.
Swindell, L. E., Electric Storage Battery Co., Chicago, Ill.
Taylor, W. O., Allis-Chalmers Mfg. Co., New York, N. Y.
Thurston, W. C., Bell Tel. Co. of Pa., Philadelphia, Pa.
Todd, P. E., New England Tel. & Tel. Co., Boston, Mass.
Van Damme, J. J. C., New York Edison Co., New York, N. Y.
Voight, J. P., Stone & Webster, Inc., Boston, Mass.
Weaver, R. C., Virginia Military Institute, Lexington, Va.
Webb, E. B., Indiana Bell Telephone Co., Indianapolis, Ind.
Weeden, E. H., General Electric Co., Schenectady, N. Y.
Wilson, R. McC., General Electric Co., Bloomfield, N. J.
Yerkes, F. C., Public Service Co. of Colorado, Denver, Colo.

Total 136.

Dastoor, M. A., Elec. Supervisor, Military Works, Bombay, India
Mayo, J. E., Northern Peru Mining & Smelting Co., Trujillo, Peru
Webster, I., Borough Council, Hamilton, N. Z.
Yoshimura, T., Bureau of Elec. Pr., Ministry of Communications, Tokio, Japan.

Total 4

STUDENTS ENROLLED MAY 16, 1924

18893 Johnson, Welton V., Univ. of Minnesota
18894 Angier, Milton S., University of Illinois
18895 Nassimbene, Charles, University of Utah
18896 Berger, Fred G., Jr., University of Denver
18897 Weekes, Edwin A., University of New Brunswick
18898 Klein, Samuel E., Pennsylvania State College
18899 Gailing, Henry A., Drexel Institute
18900 Kuppinger, Harold E., Univ. of Illinois
18901 Brightcliffe, Norman J., Drexel Institute
18902 Smith, Victor G., University of Toronto
18903 Burcham, Paul T., Engineering School of Milwaukee
18904 Lere, John E., Engineering School of Milwaukee
18905 Bender, Alfred W., Engineering School of Milwaukee
18906 Sauer, Edwin A., Engineering School of Milwaukee
18907 Letourneau, John W., Engineering School of Milwaukee
18908 Prescott, John E., Univ. of Washington
18909 Manning, Harold C., Univ. of Washington
18910 Ehrenberg, Julius Q., Rensselaer Polytechnic Institute
18911 Waltman, William H., Rose Polytechnic Institute
18912 Becker, John G., Stanford University
18913 Datta, R. S., University of Illinois
18914 Rattle, Clarence H., Univ. of Toronto
18915 Bowen, Robert M., Montana State College
18916 Morales, Justo R., Tri-State College
18917 Jacques, Henry F., Montana State College
18918 Greenberg, Elbert, Univ. of Cincinnati
18919 Drake, Frederick H., Harvard University
18920 Bruce, William R., Univ. of Colorado
18921 Franke, Leland K., Mass. Institute of Tech.
18922 Estes, Philip H., Harvard University
18923 Hauser, George L., Tri-State College
18924 Brown, Donald B., Rhode Island State College
18925 Bobb, Leo C., Tri-State College
18926 Hansen, Wesley R., Kansas State Agricultural College
18927 Parsons, Jack F., Mass. Institute of Tech.
18928 Patrick, Paul D., Tri-State College
18929 Taylor, William F., Tri-State College
18930 Wellman, Harvard University
18931 Baer, Herbert J., Pennsylvania State Coll.
18932 Shultz, Howard B., Univ. of Tennessee
18933 Fox, Claude E., University of Tennessee
18934 Watanabe, Shiezo, Harvard University
18935 Charnas, John C., Tri-State College
18936 Thompson, Albert C., Harvard University
18937 Calbick, Chester J., Wash. State College
18938 Hazen, Harold L., Mass. Institute of Technology
18939 Hazlett, Herbert M., Tri-State College
18940 Holmes, A. G., Jr., Clemson A. & M. College
18941 Chann, Thomas, Harvard University
18942 Underwood, Clarence J., Univ. of Deleware
18943 Sneed, Dan H., University of Tennessee
18944 McCandless, Carroll F., Tri-State College
18945 Gilbert, George R., Mass. Institute of Technology
18946 Warren, Lyman G., Univ. of Illinois
18947 Hirlinger, John F., Purdue University
18948 Gwinn, C. D., Purdue University
18949 Franklin, Laurence W., Purdue University
18950 Cheatham, Cader W., Georgia School of Technology
18951 McDonough, Thomas J., Georgia School of Technology
18952 Cook, Veazey M., Georgia School of Technology
18953 Newton, Frank, Georgia School of Tech.
18954 Caple, Charles A., Tri-State College
18955 Knobloch, Robert J., Univ. of Wisconsin
18956 Garrett, Richard L., Texas A. & M. Coll.
18957 Fell, William F., Drexel Institute
18958 McCauley, Raymond E., Univ. of Santa Clara
18959 Amelotti, Emil, Univ. of Illinois
18960 Mahoney, Walter D., Lewis Institute
18961 Ellis, John R., Lewis Institute
18962 Bascom, George H., Harvard University
18963 LaFollette, Marion B., Univ. of Wash.
18964 Hansen, Ted A., Univ. of Washington
18965 Bower, Kendall M., Stanford University
18966 Butler, Edward W., Stanford University
18967 Higgins, Clyde R., Stanford University
18968 Landweer, Andre E., Stanford University
18969 Litton, Charles V., Stanford University
18970 Marvin, Stanley, Stanford University
18971 Matson, Theodore M., Stanford Univ.
18972 Miller, Holmes C., Stanford University
18973 Pyzel, Ewald, Stanford University
18974 Rear, James C., Stanford University
18975 Reese, Lewis, Stanford University
18976 Rohner, Arnold J., Stanford University
18977 Rorden, Harold L., Stanford University
18978 Sah, Adam P. T., Stanford University
18979 Scofield, Philip F., Stanford University
18980 Seeger, Thomas F., Stanford University
18981 Smith, Howard C., Stanford University
18982 Walling, Curtis R., Stanford University
18983 Wight, Joe E., Stanford University
18984 Hoard, Norman F., Harvard University
18985 Taylor, Jerome J., Mass. Institute of Tech.

Total 93.

Officers A. I. E. E. 1923-1924

PRESIDENT

(Term expires July 31, 1924)
HARRIS J. RYAN

JUNIOR PAST-PRESIDENTS

(Term expires July 31, 1924)
WILLIAM McCLELLAN

(Term expires July 31, 1925)
FRANK B. JEWETT

VICE-PRESIDENTS

(Terms expire July 31, 1924)
W. I. SLICHTER (District No. 3)
R. F. SCHUCHARDT (District No. 5)
H. T. PLUMB (District No. 9)
G. FACCIOLI (District No. 1)
H. W. EALES (District No. 7)

(Terms expire July 31, 1925)
J. E. MACDONALD (District No. 8)
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S.E.M. HENDERSON (District No.10)
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WILLIAM F. JAMES (District No. 2)

MANAGERS

(Terms expire July 31, 1924)
HAROLD B. SMITH
JAMES F. LINCOLN
E. B. CRAFT

(Terms expire July 31, 1925)
R. B. WILLIAMSON
A. G. PIERCE
HARLAN A. PRATT

(Terms expire July 31, 1926)
H. M. HOBART
ERNEST LUNN
G. L. KNIGHT

(Terms expire July 31, 1927)
WILLIAM M. McCONAHEY
W. K. VANDERPOEL
H. P. CHARLESWORTH

TREASURER **SECRETARY**

(Terms expire July 31, 1924)

GEORGE A. HAMILTON F. L. HUTCHINSON

HONORARY SECRETARY
RALPH W. POPE

GENERAL COUNSEL
PARKER & AARON
30 Broad Street, New York.

PAST-PRESIDENTS—1884-1923

*Norvin Green, 1884-5-6.
*Franklin L. Pope, 1886-7.
*T. Commerford Martin, 1887-8.
Edward Weston, 1888-9.
Elihu Thomson, 1889-90
*William A. Anthony, 1890-91.
*Alexander Graham Bell, 1891-2.
Frank Julian Sprague, 1892-3.
*Edwin J. Houston, 1893-4-5.
*Louis Duncan, 1895-6-7.
*Francis Bacon Crocker, 1897-8.
A. E. Kennelly, 1898-1900.
Carl Hering, 1900-1.
*Charles P. Steinmetz, 1901-2.
Charles F. Scott, 1902-3.
Bion J. Arnold, 1903-4.
John W. Lieb, 1904-5.
*Schuyler Skaats Wheeler, 1905-6.
*Samuel Sheldon, 1906-7.
*Henry G. Stott, 1907-8.
Louis A. Ferguson, 1908-9.
Lewis B. Stillwell, 1909-10.
Dugald C. Jackson, 1910-11.
Gano Dunn, 1911-12.
Ralph D. Mershon, 1912-13.
C. O. Mailloux, 1913-14.
Paul M. Lincoln, 1914-15.
John J. Carty, 1915-16.
H. W. Buck, 1916-17.
E. W. Rice, Jr., 1917-18.
Comfort A. Adams, 1918-19.
Calvert Townley, 1919-20.
A. W. Berresford, 1920-21.
William McClellan, 1921-22.
Frank B. Jewett, 1922-23.

Deceased.

LOCAL HONORARY SECRETARIES

T. J. Fleming, Calle B. Mitre 519, Buenos Aires, Argentina, S. A.
Carroll M. Mauseau, Caixa Postal No. 571, Rio de Janeiro, Brazil, S. A.
Charles le Maistre, 28 Victoria St., London, S. W., England.
A. S. Garfield, 45 Bd. Beausejour, Paris 16 E, France.
H. P. Gibbs, Tata Sons Ltd., Navsari Building, Fort Bombay, India.
Guido Semenza, 39 Via Monte Napoleone, Milan, Italy.
Eiji Aoyagi, Kyoto Imperial University, Kyoto, Japan.
Lawrence Birks, Public Works Department, Wellington, New Zealand
Axel F. Enstrom, 24a Grefturegatan, Stockholm, Sweden
W. Elsdon-Dew, P. O. Box 4563, Johannesburg, Transvaal, Africa

A. I. E. E. Committees

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J. E. Macdonald, D. W. Roper.
Chairman of Committee on Coordination of Institute Activities.
Chairmen of Technical Committees.
Chairmen of Sections.

PUBLICATION COMMITTEE

Donald McNicol, Chairman, 132 Union Road, Roselle Park, N. J.
F. L. Hutchinson, E. B. Meyer, L. W. W. Morrow,
L. F. Morehouse.

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W. I. Slichter, Chairman, Columbia University, New York, N. Y.
F. L. Hutchinson, G. L. Knight, L. W W. Morrow.
Donald McNicol,

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Erich Hausmann, Donald McNicol,

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C. E. Magnusson, Vice-Chairman.
H. H. Henline, Herbert S. Sands, Harold B. Smith.
Chairmen of all Sections.

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F. S. Dellenbaugh, Jr., C. Francis Harding, Harold B. Smith.
Charles F. Scott,

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C. E. Baker, C. E. Fleager, H. T. Plumb.
E. E. Dorting, S. E. M. Henderson, J. F. Warwick,
John M. Drabelle, G. A. Kositzky, J. L. Woodress.
H. A. Lynette
Chairmen of local membership committees.

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F. L. Hutchinson, G. L. Knight.

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R. F. Schuchardt,

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Gano Dunn, John W. Lieb, Calvert Townley.

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A. H. Babcock, George F. Sever, C. E. Skinner.

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H. H. Cochrane, M. G. Lloyd, R. W. E. Moore,
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W. B. Hartshorne, Wills Maclachlan H. S. Warren.
L. C. Ilsley, Alexander Marks,

STANDARDS COMMITTEE

Executive Committee

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H. E. Farrer, Secretary, 33 W. 39th St., New York, N. Y.
W. A. Del Mar, A. M. MacCutcheon, F. L. Rhodes,
H. M. Hobart, J. Franklin Meyer, L. T. Robinson,
G. L. Knight, F. D. Newbury, Clayton H. Sharp
Harold Pender, C. E. Skinner.

Ex-Officio

Chairmen of Working Committees of Standards Committee
Chairmen of A. I. E. E. delegations on other standardizing bodies.

EDISON MEDAL COMMITTEE

Appointed by the President for term of five years.

(Term expires July 31, 1924)

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Street Lighting.—Booklet, 12 pp. Describes in detail the construction and application of the new asymmetric 2-way and 4-way refractors for street lighting purposes. The advantage of these two new asymmetric refractor types over the old symmetric refractors is that the light is confined to the street and is not wasted on adjacent buildings. These refractors are especially desirable for residence streets. Holophane Glass Company, Inc., 342 Madison Avenue, New York.

Performance of Instrument Transformers.—Catalog S. P., 32 pp. Analyzes the factors underlying the performance of both current and voltage transformers and gives complete information for the application of these transformers to an electrical system. Wiring diagrams for instrument transformers have been included in the publication, together with a table of operating constants for Westinghouse instruments. Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

Automatic Control System.—Bulletin, 4 pp. Describes the Trent automatic control system, a temperature gage combined with an automatic control which indicates the temperature of the apparatus and at the same time controls the temperature to any value within the range of the scale. Used in connection with electrical heated devices, gas, oil, steam or air heated appliances, operating air or fuel valves, etc. H. E. Trent, 1524 Chestnut Street, Philadelphia, Pa.

NOTES OF THE INDUSTRY

Name Change.—The former U. S. Ball Bearing Manufacturing Company, Chicago, Ill., manufacturers of Strom Ball Bearings is now the Strom Ball Bearing Manufacturing Company. No changes have been made or are contemplated in the organization's personnel.

Name Change.—The Copper Clad Steel Company, Rankin, Pa., has changed its name to the Copperweld Steel Company, to conform to the principal product of the company—known as Aristos Copperweld Wire.

Kuhlman Electric Company, Bay City, Mich., manufacturer of power, power distribution and street lighting transformers, has opened a sales office at 300 Madison Avenue, New York, in charge of D. F. Potter, Jr.

The Triumph Electric Company, Cincinnati, O., has appointed the Miller-Selden Company of Detroit, exclusive sales representatives in Detroit and vicinity for the line of self-start type T R 2, slip ring, squirrel cage and direct current motors.

The National Carbon Company has moved its Chicago brush finishing plant from 560 West Congress Street to new and larger quarters, located at 551 West Monroe Street. The new location will enable the company to double its output and thus extend better service to their customers in the Chicago district.

Voltage Surge Recorder.—A new instrument known as the Klydonograph has been developed by J. F. Peters of the Westinghouse Electric & Manufacturing Company for recording abnormal voltages on transmission lines. With this instrument a graphic record of voltage surges of extremely short duration can be obtained, giving their polarity, magnitude, steepness of application, etc.

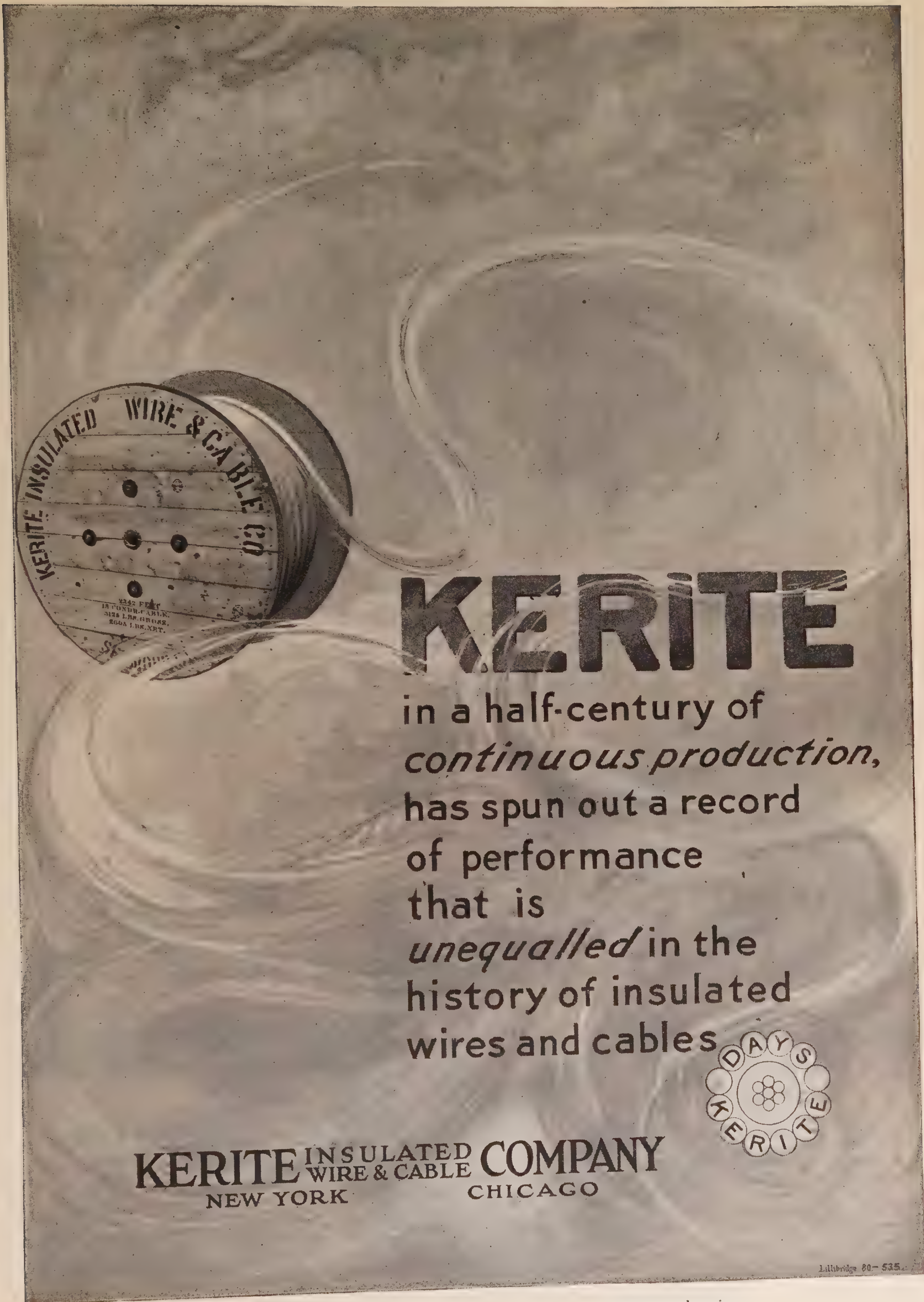
The Allis-Chalmers Manufacturing Company, Milwaukee, Wis., have taken over the power and mining works of the Worthington Pump & Machinery Company at Cudahy, Wis. The Worthington Company has discontinued its crushing, cement, mining and creosoting lines, and the Allis-Chalmers Company have acquired all of the records, patents and manufactured stock, etc., pertaining to these lines.

The Bristol Company, Waterbury, Conn., manufacturer of recording instruments and distributors of radio equipment, has leased space in the Larkin building, 3617 So. Ashland Avenue, Chicago, in order to adequately take care of the middle west business, which has grown to large volume. The space will be devoted to repairing and recalibrating Bristol instruments in Chicago territory, and for stocking radio merchandise. The present salesroom and offices of the Bristol Company will be maintained in the Monadnock Building.

Crocker-Wheeler Company, Ampere, N. J.—At a recent annual meeting of the company the following officers were re-elected; Edmund Lang, President; Arthur L. Doremus, Vice-President; Herbert C. Petty, Secretary; Theodore S. Fuller, Treasurer; George W. Bower, Assistant Secretary and Assistant Treasurer. The company's directors were re-elected and in addition Theodore S. Fuller and Herbert C. Petty were added to the Board.

Negative Phase-Sequence Relay.—A new relay designed to protect polyphase motors and rotary converters against running with one of the phases open (phase failure) with a reversal of phase rotation, or with phases sufficiently unbalanced to cause undue heating in the machine, has been developed by the Westinghouse Electric & Manufacturing Company. The relay is made up of four branches, consisting of an induction relay element, two reactors, and one resistor, which are all mounted in one case. This network is connected to two current transformers which are connected in two of the three phases of the polyphase circuit.

Square Instruments for A-C. Switchboards.—A complete line of rectangular shaped instruments for a-c. switchboards, including d-c. instruments for the exciter panels, has been developed by the Weston Electrical Instrument Company, of Newark, New Jersey. All of the instruments have uniform case dimensions of 5¾″ wide and 6″ high. This affords a considerable saving of space favoring the rectangular type over the round pattern type in the ratio of 5 to 9, on a typical four-circuit panel. This has been accomplished without sacrificing any of the qualities of the Weston round pattern instruments. In addition to the economy of space, these rectangular instruments have the same scale lengths as the corresponding round pattern instruments, a much better scale illumination and greater legibility due to the wide scale opening and bold type of arcs and figures.


KERITE INSULATED WIRE & CABLE CO
KERITE
in a half-century of
continuous production,
has spun out a record
of performance
that is
unequalled in the
history of insulated
wires and cables
DAYS
KERITE
KERITE INSULATED WIRE & CABLE COMPANY
NEW YORK
CHICAGO

Strom BALL BEARINGS

An Old Company — a New Name

The trade-mark and the product haven't changed —only the Company name is different

IN the future—Strom Ball Bearings will be manufactured by the Strom Ball Bearing Manufacturing Company. Thus the product, and the company that makes it, will have the same name.

The name "STROM" on a ball bearing is an asset.

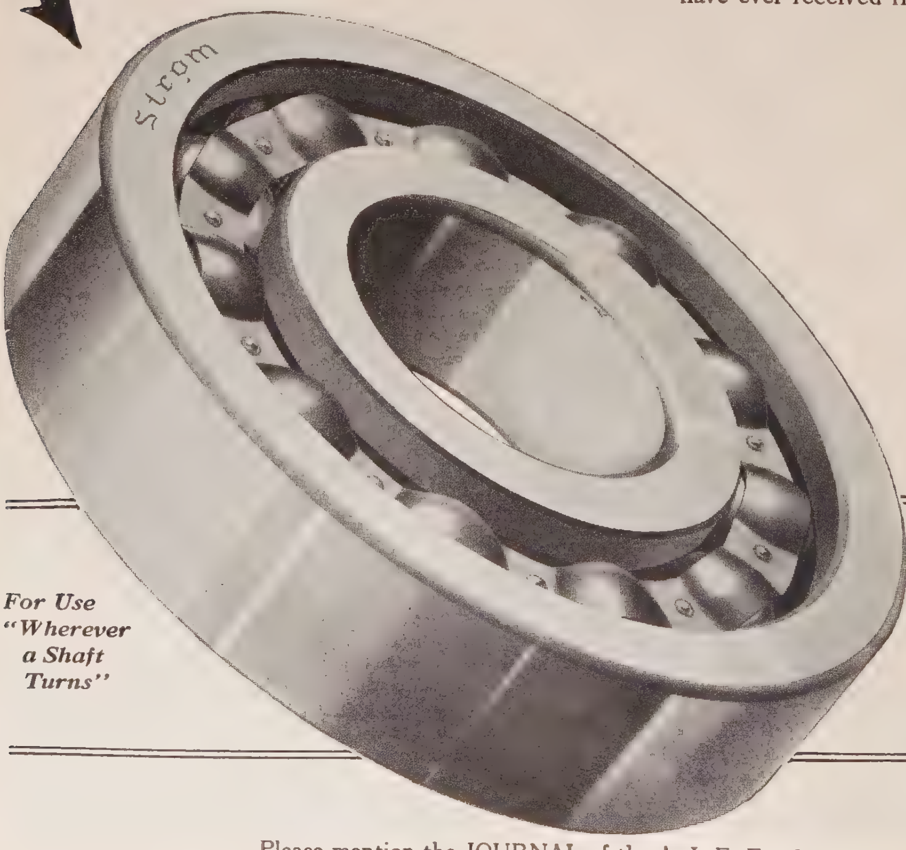
It is the trade-mark of a superior product, made in a superior way.

So we decided to change the name of our corporation to embody this valued trade name.

No changes have been made in the company personnel. The high manufacturing principles which have governed this concern's business will remain the same.

Strom Ball Bearings will still be made with that exact scientific precision and that devotion to perfection for which they have been noted in the past.

Our service will keep on improving, as it has improved in the past. And we ask for our company a continuation of the same kind and generous consideration which we have ever received from the trade.



Our engineers are at your service. Consult them freely.

Our ample stocks are ready to meet any emergency calls. Strom Ball Bearings are made in a wide range of sizes and styles, ready to meet your requirements.

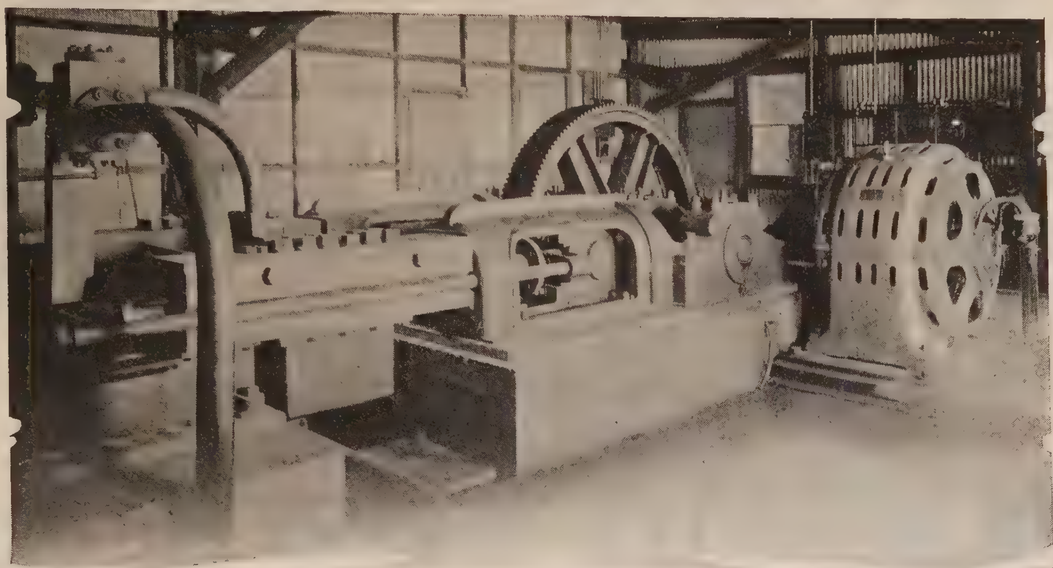
For Use "Wherever a Shaft Turns"

Strom Ball Bearing Mfg. Co.

(Formerly U. S. Ball Bearing Mfg. Co.)

4595 Palmer St., Chicago, Ill.

SKF



Municipal Cotton Press

Los Angeles Harbor—San Pedro—California

SPECIFICATIONS

MOTOR—300 H. P. FAIRBANKS-MORSE ball bearing motor, 3 phase —60 cycle—440 volt—slip-ring.

Which drives through flexible coupling to herring bone pinion and gear.

PUMP — 4½" x 15" duplex high pressure pump operating.

COMPRESSOR—Plunger—24"; Stroke —7'; Pressure Plate—43" x 22".

This machine compresses both from the ends and sides a 500 pound bale of cotton reducing it from original dimensions of 36" x 30" x 56" to 22" x 30" x 48".

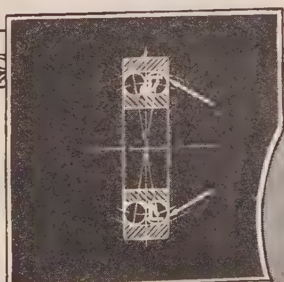
A large part of the cotton produced in the Imperial Valley in Southern California and Arizona is compressed in this press.

Our engineers will gladly aid in solving your bearing problems.

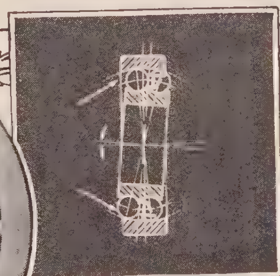
THE SKAYEF BALL BEARING COMPANY

Supervised by SKF INDUSTRIES, INC., 165 Broadway, New York City

1132



Normal View



Deflected View

PRECISION

OPEN TYPE NORMA BEARING

What Precision Means

Precision, in its common usage, is a term defining extreme refinement of dimension and finish. But to us who manufacture and sell "NORMA" Ball Bearings and "HOFFMANN" Roller Bearings, precision has a far more comprehensive meaning. It means also bearing designs worthy of expression in a structure of extreme refinement, and superior metals worthy of special treatments and highly refined machining processes.

To you who manufacture, sell or use electrical machinery, "precision" in anti-friction bearings means longer life, greater serviceability—, higher speed qualities, better performance, lower costs.

STANDARD HOFFMAN BEARING

"NORMA"

BALL BEARINGS

For High-Speed, High-Duty Performance

Where the utmost of serviciability must be had under long-continued operation at high speeds—there is the recognized place of "NORMA" Precision Bearings in the electrical industries. Proved by the tests of time and service, they have been progressively bettered to meet ever harder conditions—rather than cheapened to meet low-price competition. They are daily demonstrating their superlative dependability in hundreds and hundreds of thousands of motors and generators where the failure of a bearing would mean losses a thousand times the cost of the original bearing equipment.

"HOFFMAN"

ROLLER BEARINGS

For Heavy Loads and Hard Service

Speed qualities equal to those of the best ball bearing, combined with a steady load capacity far beyond that of any ball bearing and a temporary overload capacity which no ball bearing has—these distinctive features suggest the field for "Hoffmann" Precssion Roller Bearings in the electrical industries. Where the duty is hardest and the operating conditions most difficult and the necessity for stand-up-ability the greatest—there do "Hoffman" Roller Bearings reveal their true value and return the dividends which justify their use.

"NORMA" engineers will welcome an opportunity to work with yours in applying these high-precision bearings to high-duty electrical machinery.

CLOSED TYPE NORMA BEARING

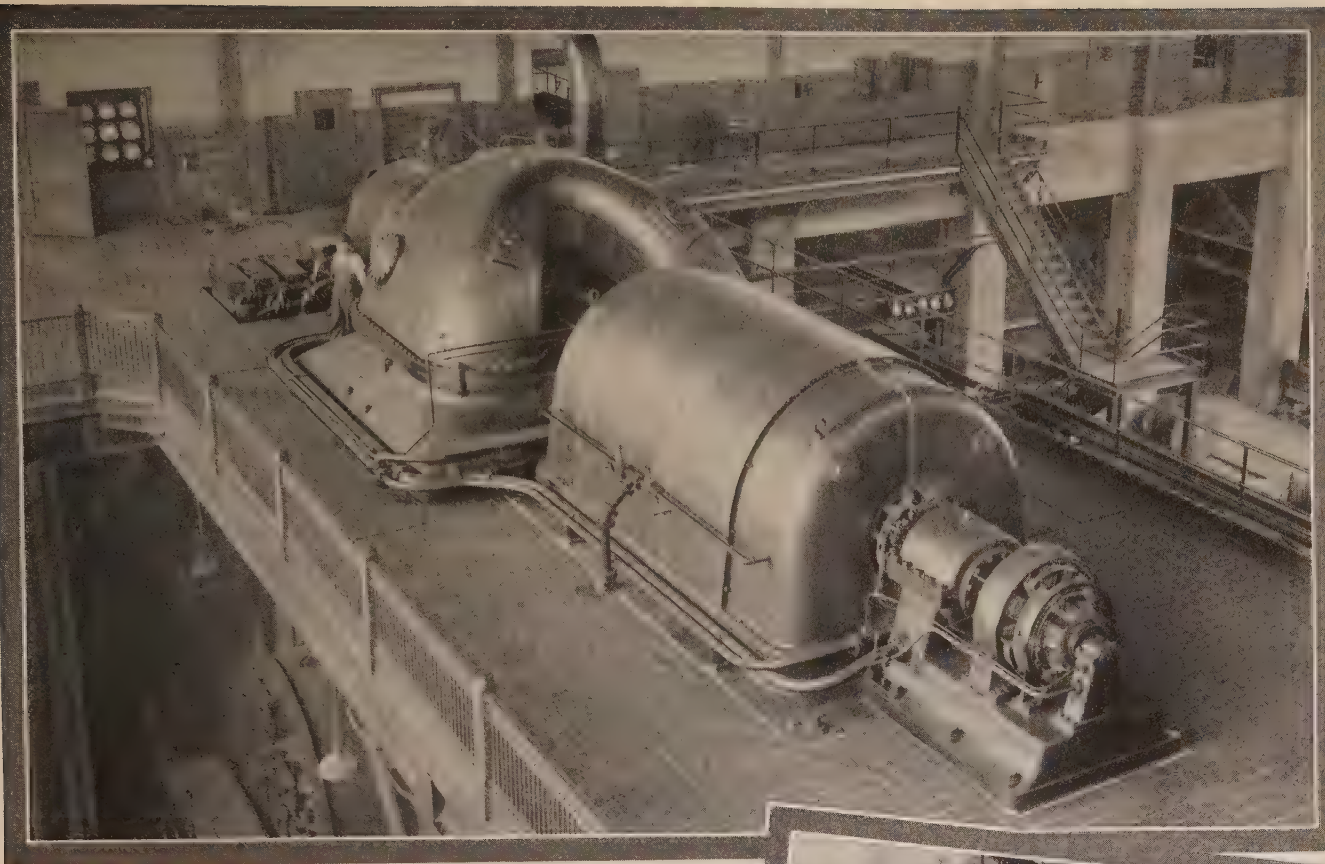
THE NORMA COMPANY OF AMERICA

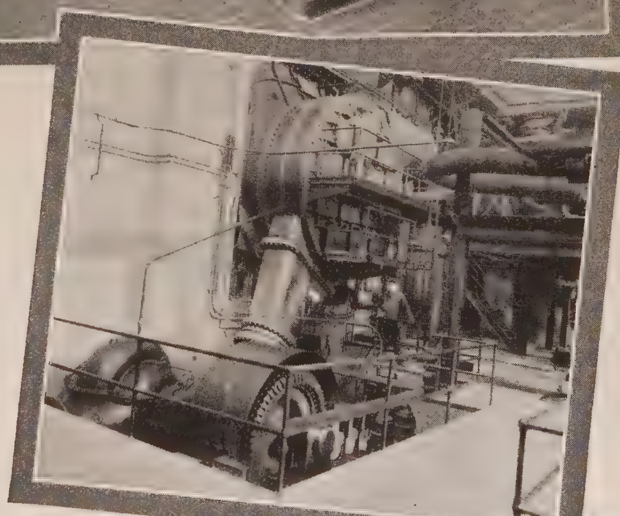
Anable Avenue Long Island City New York

BALL, ROLLER AND THRUST BEARINGS

ENCLOSED SELF-ALIGNING HOFFMAN BEARING

BEARINGS





Allis-Chalmers equipment now in operation in Waukegan Station, Public Service Company of Northern Illinois

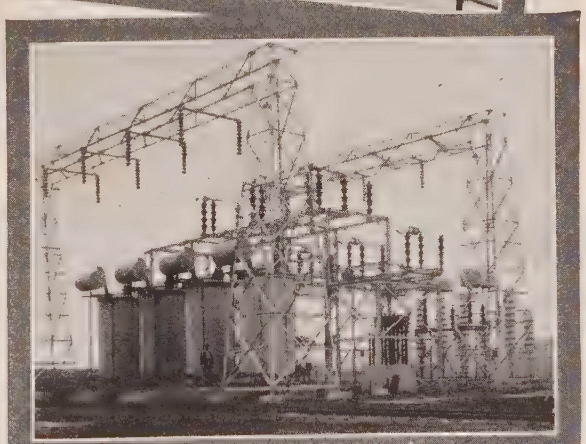
20,000 K. W., 80% P. F., 1800 R.P.M. Steam Turbine and Alternator Unit.

32,000 sq. ft. Surface Condenser.

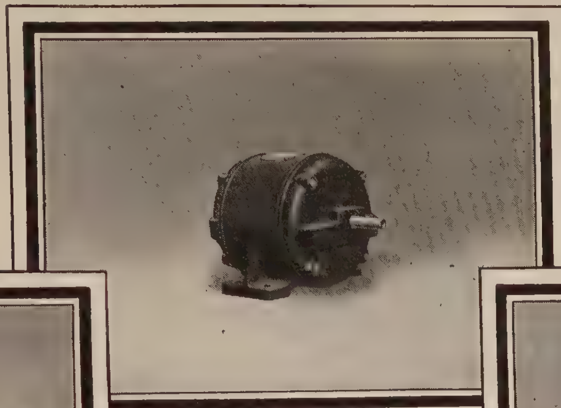
1—36 in. Type "LS" Single Stage, 35,000 G.P.M., 25 ft. hd., 435 R.P.M., Circulating Pump driven by 300 H.P. two speed Motor.

2—4 in., Type "CS" Single Stage, 600 G.P.M., 150 ft. hd., 1750 R.P.M. Condensate Pumps each with 30 H.P. Motor.

4—10,000 KV-A., 145,000 Volt, Oil Insulated Water Cooled Transformers.

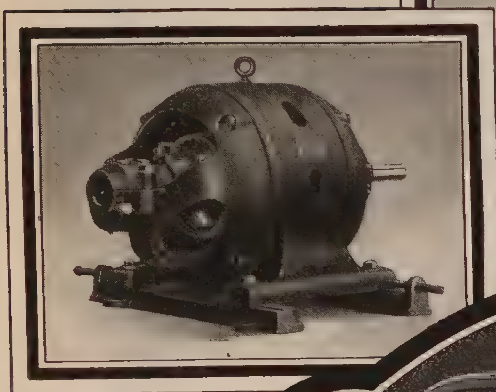


FACTURING COMPANY
SCONSIN U.S.A.

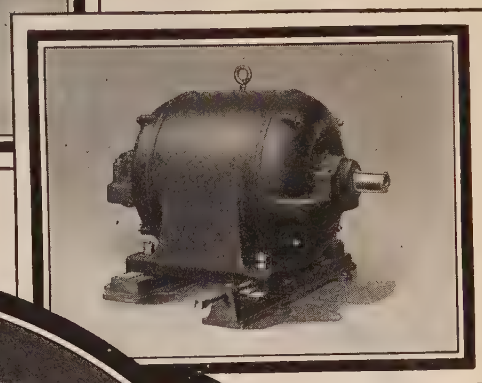


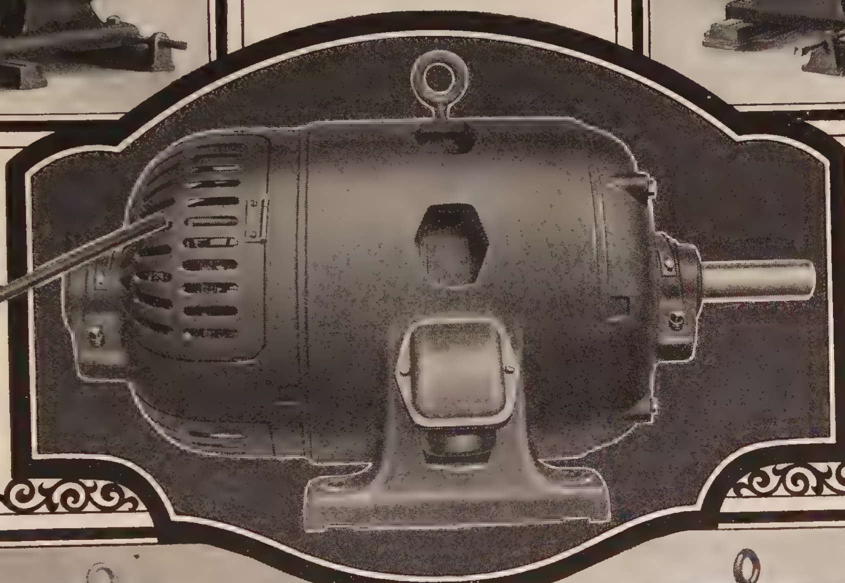
Wagner BB-type Split-phase Motor.

Wagner BA-type Repulsion-induction Motor.



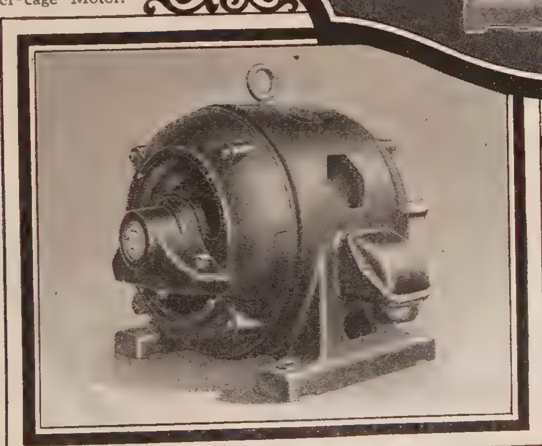
Wagner BR-type Slip-ring Motor.



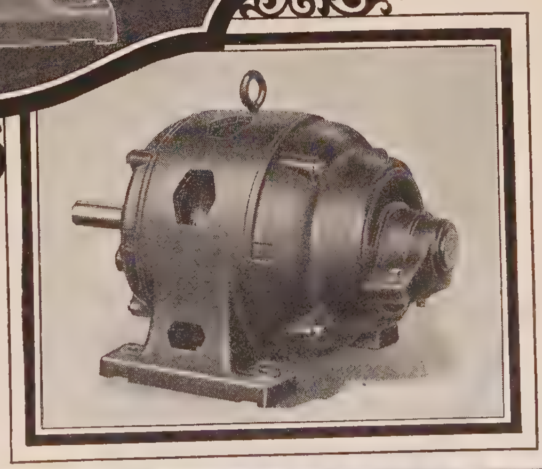


Fynn-Weichsel, the motor that corrects power-factor.

Wagner Pow-R-full Type Squirrel-cage Motor.



Wagner Pow-R-full Type Starterless Motor.



WAGNER ELECTRIC CORPORATION
SAINT LOUIS

WAGNER ELECTRIC CORPORATION

You may send me—without obligation on my part—a copy of your bulletin No. 134, describing THE FYNN-WEICHSEL MOTOR.

NAME

COMPANY

STREET

CITY STATE

A Complete Line of Alternating-Current Instruments

In both 4⅜-inch and 7½-inch sizes

Including Ammeters, Voltmeters, Power-Factor Meters, Frequency Meters and Wattmeters.

Readings practically unaffected by frequency, wave form or temperature, Wattmeters are free from errors due to power-factor and unbalance.

Complete open face increases readability.

Scale divisions widest at important operating loads.

Reduced weight of meter, with reduced weight movement on bearings, assure longer life.

Lithographed metal dials, hand marked.

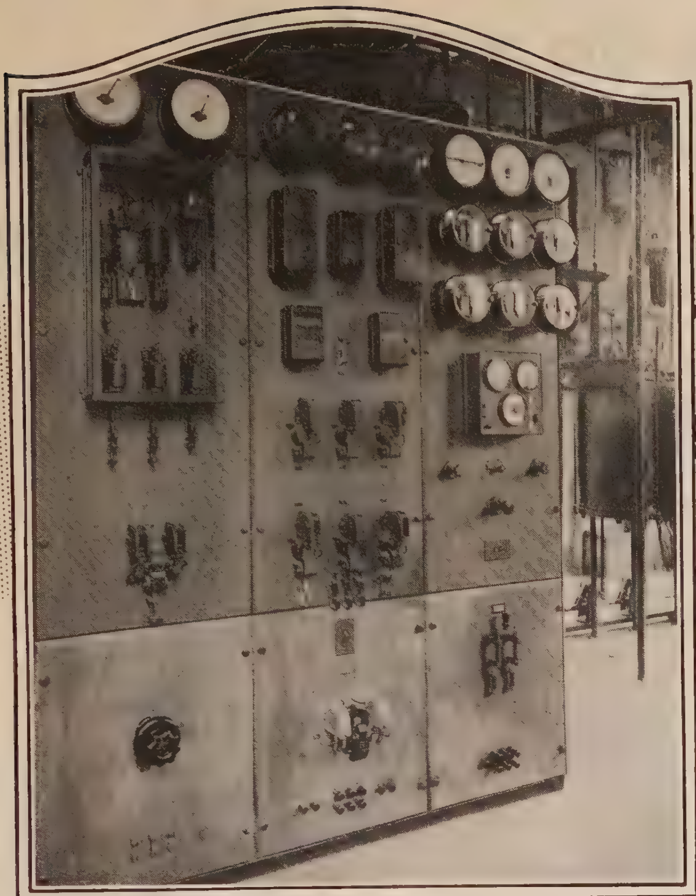
Circular 1664 contains complete information. Send for it.

Westinghouse Electric & Manufacturing Co.
East Pittsburgh, Pa.

Sales Offices in All Principal Cities of the United States and Foreign Countries

WESTINGHOUSE ELECTRIC

Westinghouse



WESTINGHOUSE ELECTRIC

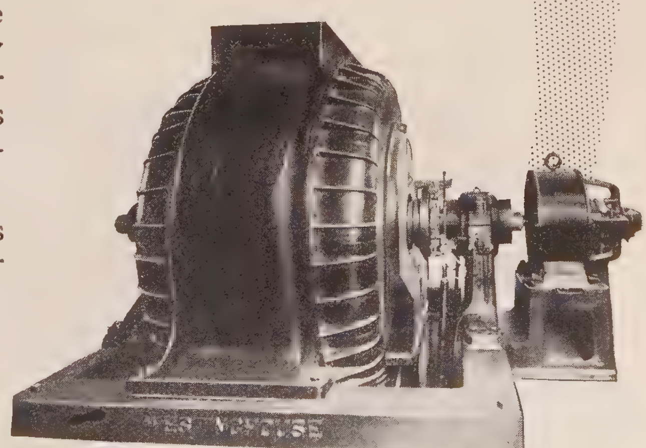
Meet the New Operator

At the Madera Substation of the Penn Public Service Company, Westinghouse Automatic Switching Equipment controls a 5,000 kv-a. synchronous condenser used for line regulation.

Westinghouse Automatic Switching Equipment not only reduces expense by eliminating the operator but effects great economy in the transmission of power over long distance by automatically increasing the power factor when needed. Since the installation of this equipment it has been possible to greatly reduce the system's generating capacity.

Let our engineers show you other examples of this nature. Write our nearest office for detailed information.

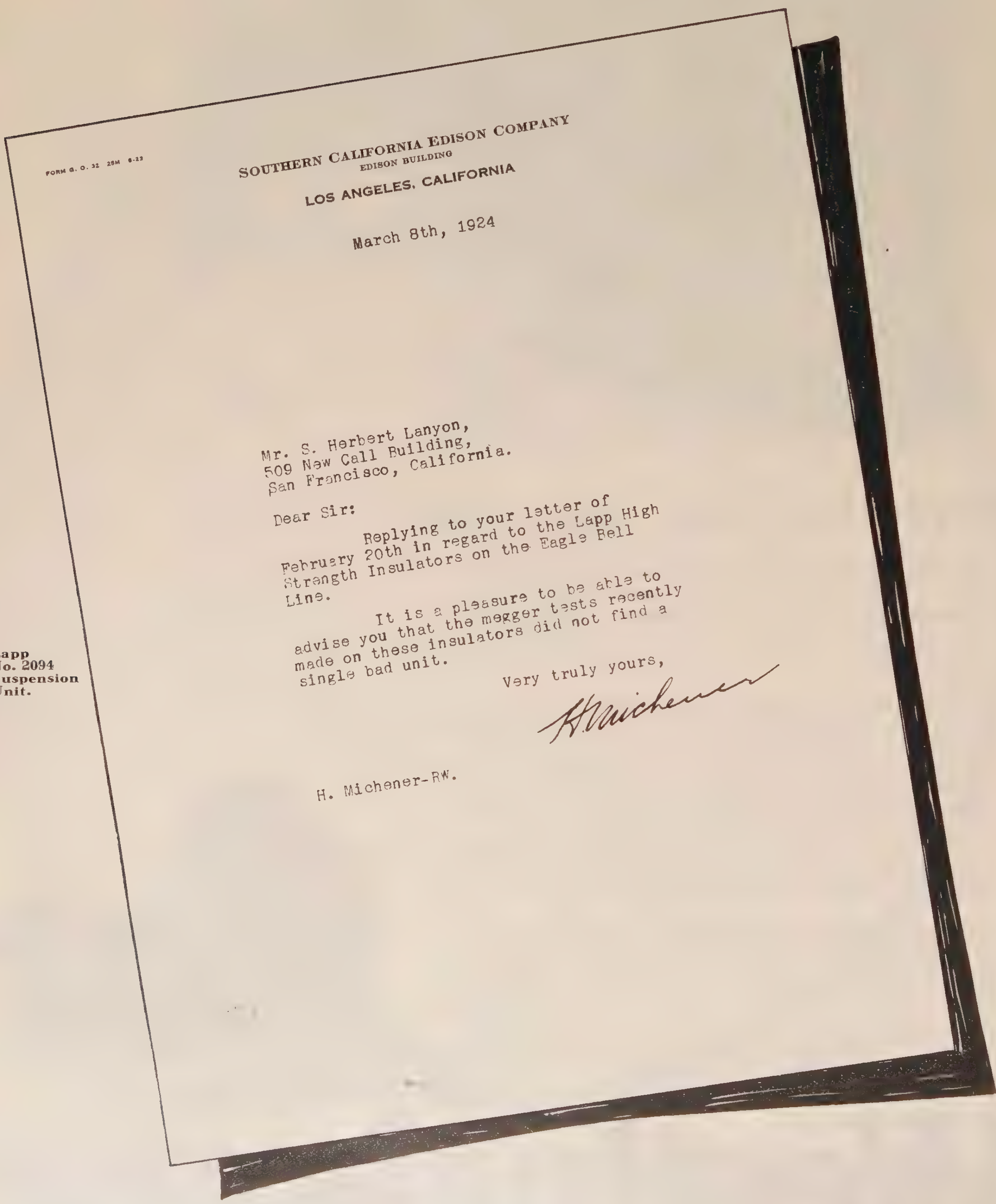
Westinghouse Electric & Manufacturing Company
East Pittsburgh Pennsylvania
Sales Offices in All Principal Cities of the
United States and Foreign Countries



Westinghouse

Lapp Insulators do not fail!

—they are the result of straight-line thinking



FORM G. O. 32 25M 8-23

SOUTHERN CALIFORNIA EDISON COMPANY
EDISON BUILDING
LOS ANGELES, CALIFORNIA

March 8th, 1924

Mr. S. Herbert Lanyon,
509 New Call Building,
San Francisco, California.

Dear Sir:

Replying to your letter of February 20th in regard to the Lapp High Strength Insulators on the Eagle Bell Line.

It is a pleasure to be able to advise you that the megger tests recently made on these insulators did not find a single bad unit.

Very truly yours,

H. Michener

H. Michener-RW.

Lapp No. 2094 Suspension Unit.

Lapp Super-Strength High-Voltage Insulator

Patent Pending

Assembled

The design illustrated we are manufacturing for minimum ultimate strength, ***without electrical failure,*** of 300,000 pounds. The porcelain withstands over 550,000 pounds, ***without failure.***

This design can be supplied for mechanical ultimate strengths from 40,000 to 400,000 pounds, ***without electrical failure*** and for electrical flashover up to 130,000 volts per unit.

The design has the following qualities:

1. Less size and first cost and much less erection cost than standard suspension insulator strings used in multiple (where for nominal loads such method is feasible) but, after such multiple strings become impracticable because of complications for very high loading, this design continues up in strength to values many times those possible heretofore and gives at all times a very definite security factor.

2. The span cannot drop unless metal parts fail, because co-acting metal parts are interlocked. To guard against failure of any kind in service, each insulator is proof-tested at our factory to the full guaranteed strength, be it 40,000 or 400,000 pounds.

3. Insulators cannot puncture, because the voltage drop is taken through a long length of porcelain, instead of through a limited **thickness** as in ordinary insulators. It is even inconceivable that lightning could injure the insulator.

4. The design is such that an arc will not form nor shift over the surface of the porcelain.

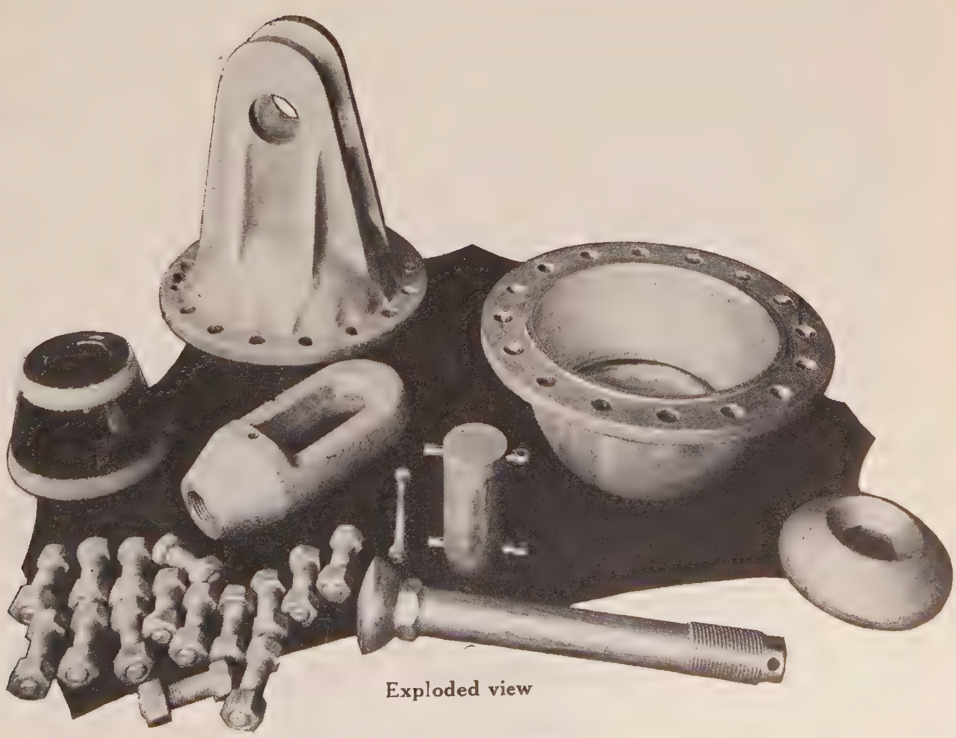
5. Very low wind resistance.

6. Very low erection cost.

7. Very low weight/strength ratio.

You have available, therefore, simple responsible insulators for any voltage and any length span for which you can obtain a conductor.

LAPP INSULATOR CO., Inc.
LeROY, N. Y., U. S. A.



Exploded view

Most Insulators Look Alike

It takes a keen eye to detect the slight variation in design which may distinguish one make of insulator from another when up on the line.

Under ordinary conditions there is no noticeable difference in the service of good insulators. The factor of safety under *abnormal* conditions is the measure of the efficiency of an insulator.

Lightning, surges, wind and sleet loads, reveal the quality of the porcelain and the efficiency of the design of the insulator.

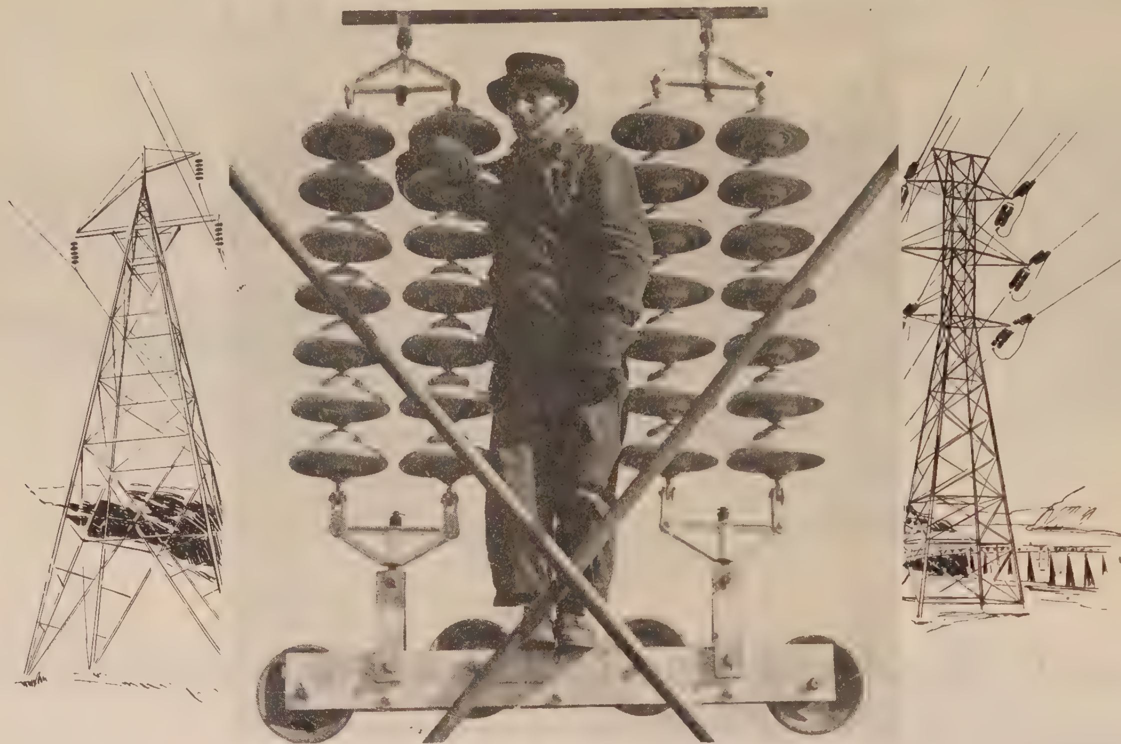
The scientific choice and preparation of materials, careful attention to manufacturing details, thorough inspections in all stages of manufacture—are the Locke methods which insure continuous line service under all operating conditions.

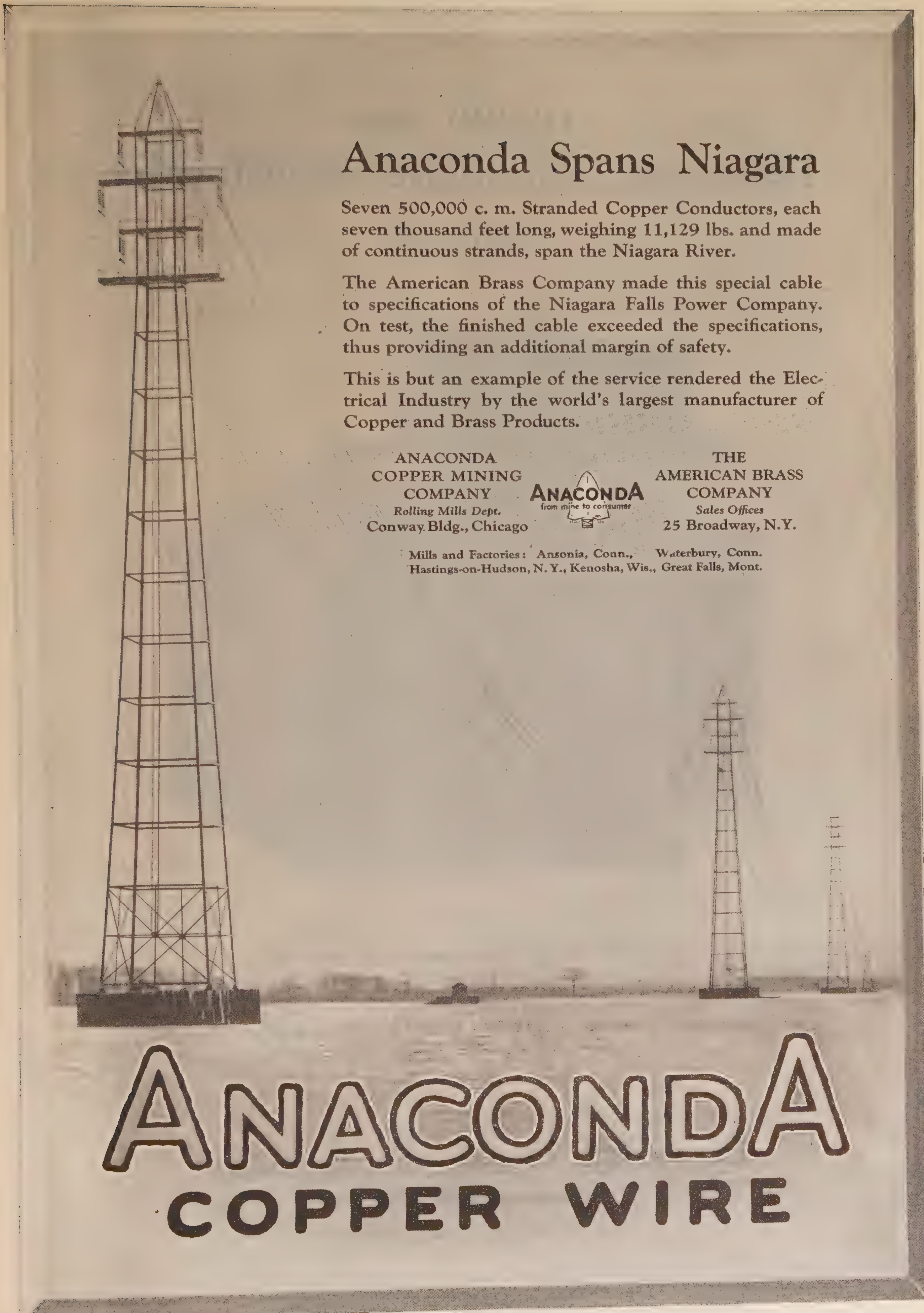
The porcelain is the insulation. Locke Porcelain makes possible Locke Insulators.

LOCKE INSULATOR CORPORATION
Baltimore, Md., and Victor, N. Y.

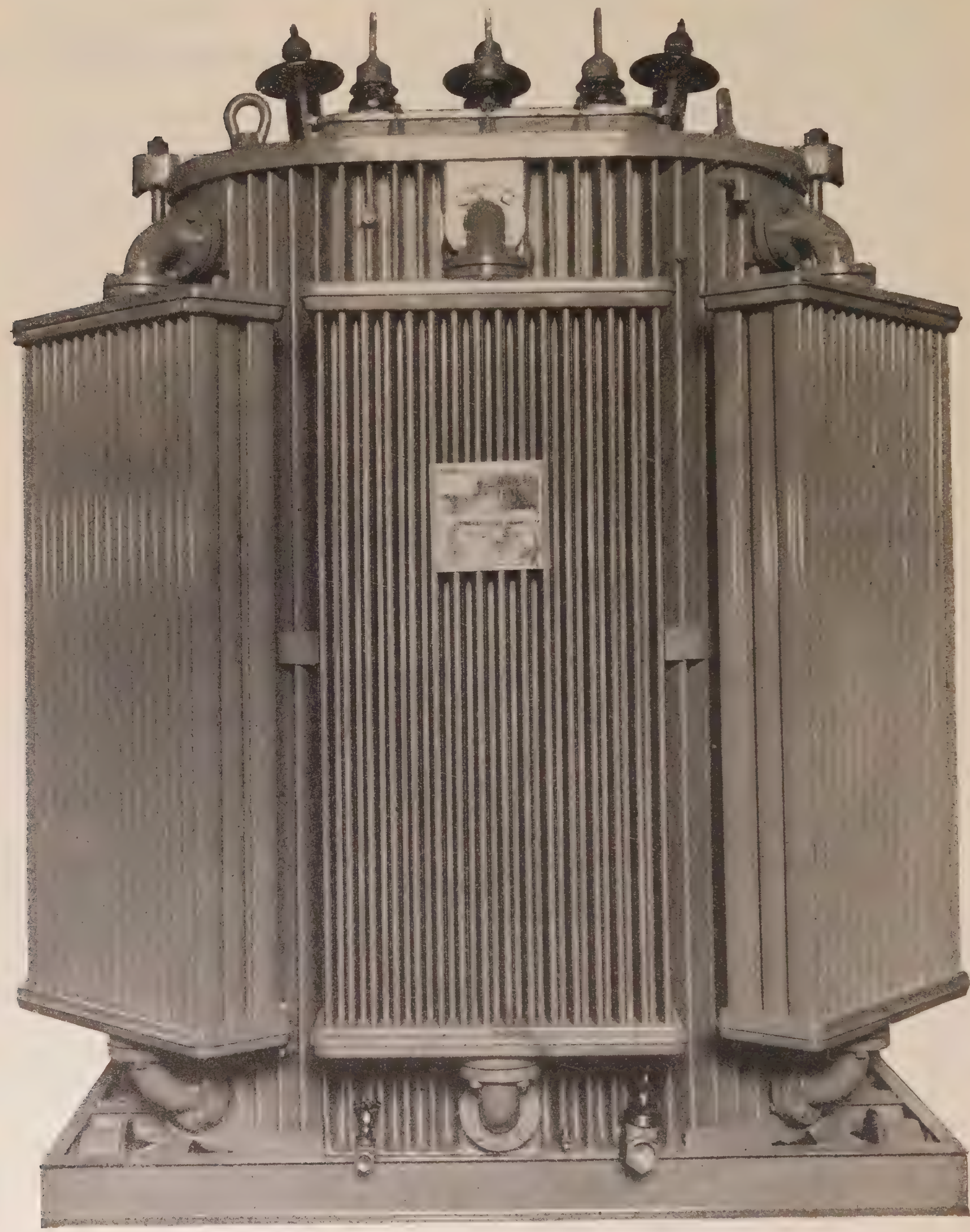
LOCKE
PORCELAIN


THOMAS QUALITY
INSULATORS
The American Standard since '73.




Anaconda Spans Niagara
Seven 500,000 c. m. Stranded Copper Conductors, each seven thousand feet long, weighing 11,129 lbs. and made of continuous strands, span the Niagara River.
The American Brass Company made this special cable to specifications of the Niagara Falls Power Company. On test, the finished cable exceeded the specifications, thus providing an additional margin of safety.
This is but an example of the service rendered the Electrical Industry by the world's largest manufacturer of Copper and Brass Products.
ANACONDA COPPER MINING COMPANY
Rolling Mills Dept.
Conway Bldg., Chicago
ANACONDA
from mine to consumer
THE AMERICAN BRASS COMPANY
Sales Offices
25 Broadway, N.Y.
Mills and Factories: Ansonia, Conn., Waterbury, Conn. Hastings-on-Hudson, N. Y., Kenosha, Wis., Great Falls, Mont.
ANACONDA
COPPER WIRE

As Good as They Look

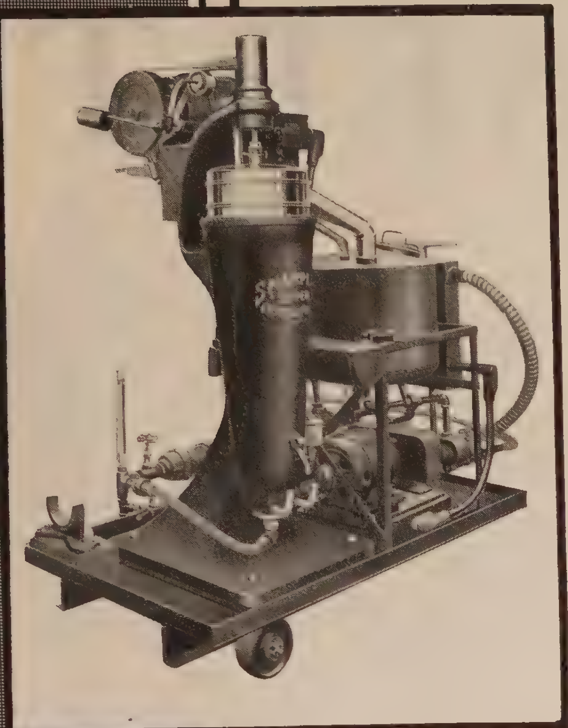


Packard Transformers are built throughout in accordance with the ideals which in the last third of a century have made "Packard" synonymous with surpassing craftsmanship.

Power — Distribution — Metering — Series Circuit Regulating — for every service. Stock of Distribution Transformers stocked in San Francisco.

The Packard Electric Company Warren Ohio

Transformer Manufacturers Since 1890



SECURING and retaining a dielectric strength of Transformer Oils is no longer a tedious, difficult problem. A great force—generated in the SHARPLES Super Centrifuge—eliminates all impurities such as water, fibre, dirt and sludge in Transformer Oils.

* * *

The SHARPLES Portable Super Centrifuge develops two and a half times the Centrifugal Force generated in any similar device. This high Centrifugal Force is positive assurance that Transformer Oils—when Super Centrifuged—will always have a greater dielectric strength than specified by the N. E. L. A.

* * *

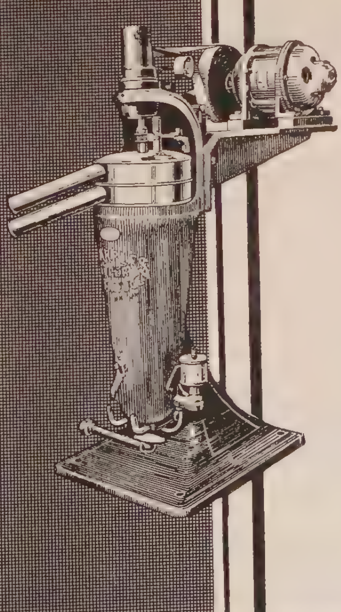
The SHARPLES Super Centrifuge is obtainable in a dual purpose Portable Machine. It is both a Dehydrator and Clarifier, being used on Turbine or Diesel Engine Oil and on Transformer Oil.

* * *

SHARPLES Engineers have important information—which you should have—on the subject of the purification of Transformer Oils.

THE SHARPLES SPECIALTY COMPANY
2300-2324 Westmoreland Street
Philadelphia, Pa.

Representatives in all principal Industrial territories



SHARPLES SUPER CENTRIFUGAL FORCE

A Great Force

G&W ELECTRIC SPECIALTIES

POTHEADS

Any size—any voltage—any number of conductors—any combination of cables—in fact, anything you want for the end of your cable.

Large stocks, quick delivery, intelligent engineering backed by experience and *smiling service.*

Investigation of what we can furnish for a given layout is worth while for many reasons you will quickly appreciate.

Let our engineers show you the operating economy that results from a small expenditure and the proper application of *G & W Potheads* and *Boxes.*

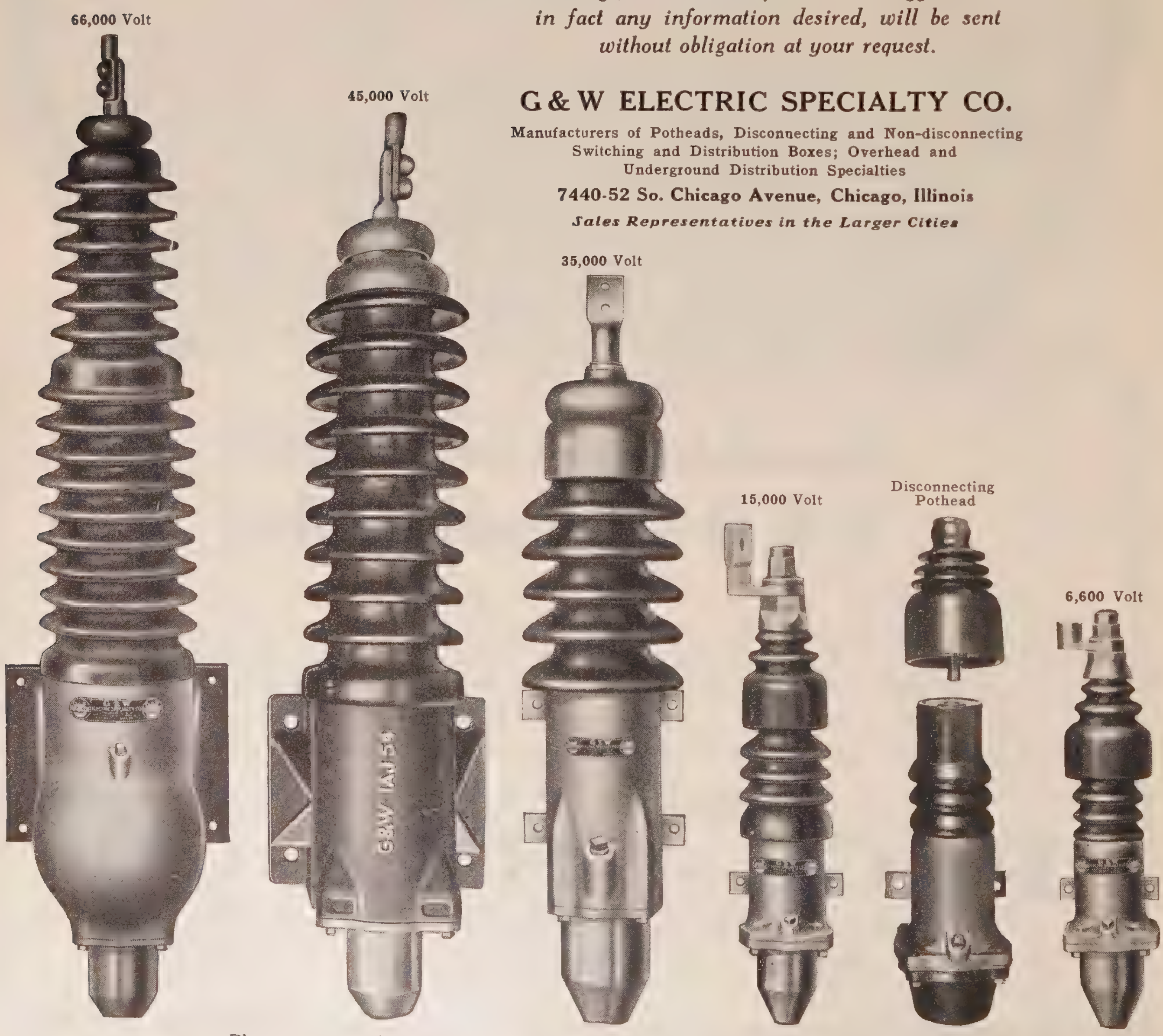
Catalogs, Blue Prints, prices and suggestions, in fact any information desired, will be sent without obligation at your request.

G & W ELECTRIC SPECIALTY CO.

Manufacturers of Potheads, Disconnecting and Non-disconnecting Switching and Distribution Boxes; Overhead and Underground Distribution Specialties

7440-52 So. Chicago Avenue, Chicago, Illinois

Sales Representatives in the Larger Cities




1950
A Message From Mars
"EARTHLY CONTROL BY DEAN SYSTEM"
STATION LOAD INDICATORS
REMOTE WATER GAUGE
REMOTE VALVE CONTROL
SWITCHBOARD
CHIEF ENGINEER
TURBINE AND BOILER ROOMS
PAYNE DEAN LIMITED
STAMFORD, CONN.

Some Static Condenser Facts

The manufacture of static condensers and their application to power factor correction is an economic problem, involving as it does *reliability* in operation, reasonable *initial cost* and the question of *size and weight*. These factors have a definite relation to the quality of the condenser dielectric:

Reliability. Ordinary insulating materials operated at stresses equivalent to those utilized in other electrical apparatus may give a reliable condenser, but at the sacrifice of cost, weight, and dimensions.

Initial cost. The corrective capacity obtained from a given area and thickness of dielectric varies directly as the square of the applied voltage. An increase of 100% in working stress on the dielectric gives four times the corrective capacity at approximately ¼ the cost per kv-a.

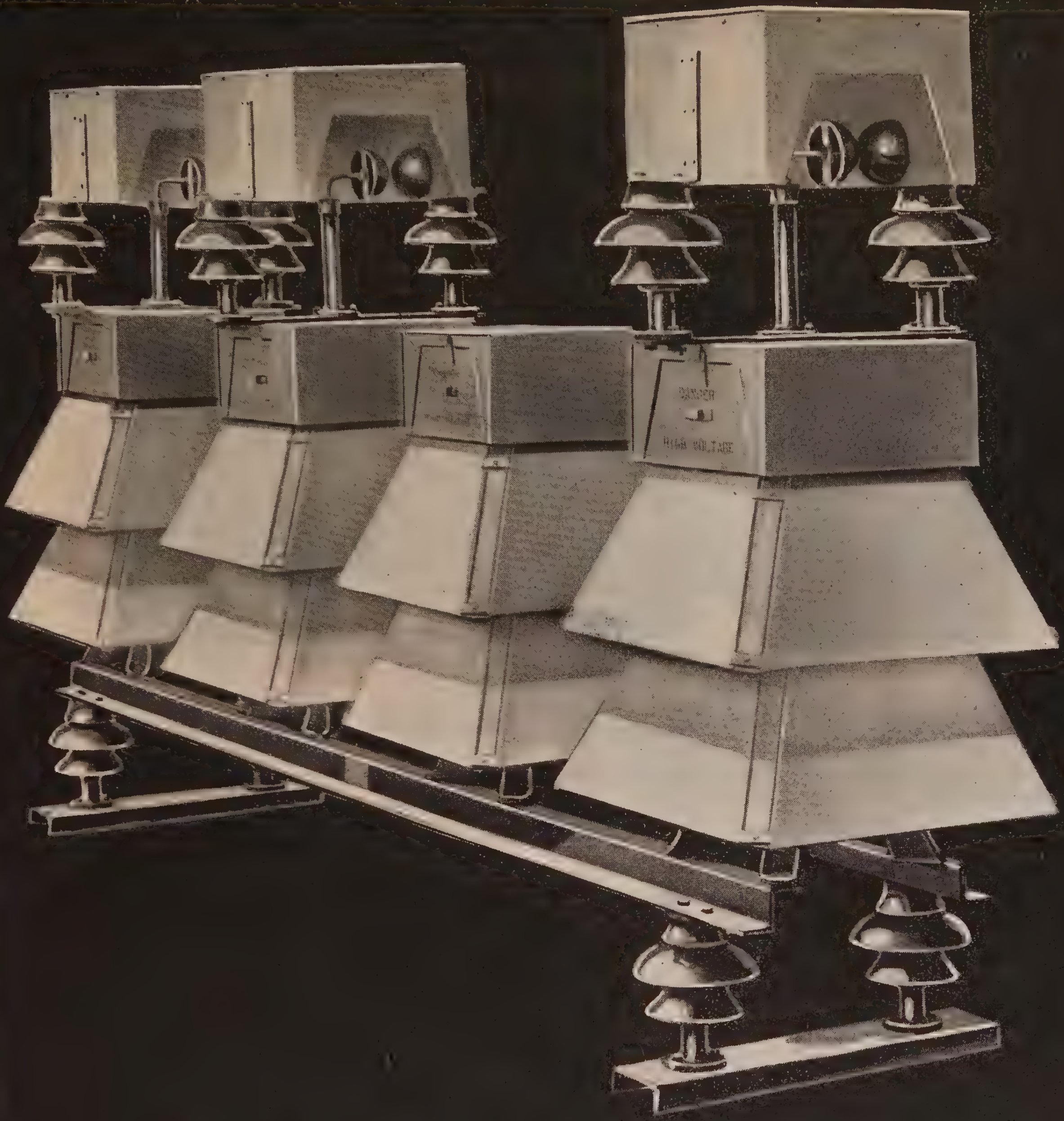
Size and weight. With a high-quality dielectric one half the thickness can be used for a given voltage and twice the active area can be contained in a given volume. This means ¼ the volume and weight for a given rating of equipment.

The principle underlying G-E Static Condenser design is the use of a superior dielectric to permit a high working stress and obtain these advantages of low cost and minimum size and weight. G-E Static Condensers today contain an improved dielectric of a quality never before obtained.

General Electric Co. **Schenectady, N. Y.**

33A-200

GENERAL ELECTRIC



11,000 Arrester-years of Service

are behind your purchase of station-type Oxide Film Arresters

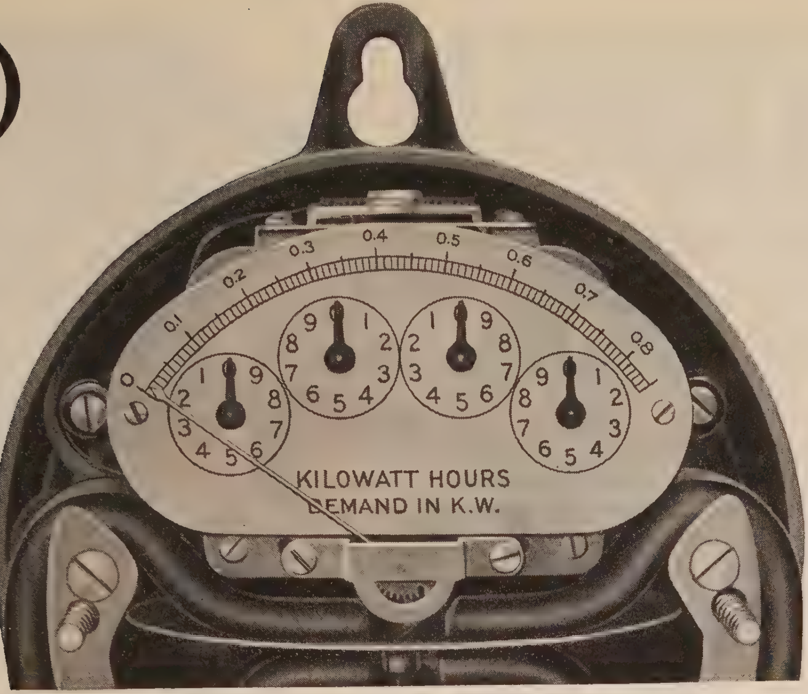
An arrester worthy of the name must protect apparatus against lightning disturbances, at the same time protecting itself, and must do this indefinitely. The Oxide Film Arrester does.

General Electric Company
Schenectady, N. Y.
Sales Offices in all Large Cities

GENERAL ELECTRIC

33E-44

SANGAMO



Do not estimate maximum demand—*measure it*

It's the cheaper and the only equitable way

ESTIMATING a customer's probable maximum demand is hardly any fairer than estimating his probable monthly energy requirements and doing without watthour meters. Periodic estimates of customers' demands are expensive and inaccurate and do not permit of ready adjustment of rates if a customer's demand increases or decreases. The consumer is seldom satisfied with the rate he gets for he knows that the estimate of his demand is but little better than a mere guess. The only equitable basis for making demand charges is to determine accurately the *actual* maximum demand that has occurred between regular monthly meter readings.

This is exactly what the Sangamo Maximum-demand Register permits you to do. It combines in one unit a watthour register, a demand register and a timing device, indicating on a single dial the energy consumption and the maximum demand that has occurred since the last meter reading and resetting.

A high degree of accuracy is obtained in both energy and demand indications as the result of a number of features of which the following are the most important.

Very little torque is required to advance the demand-indicator hand thus placing practically no additional load on the rotating element of the meter.

Constant time intervals—a most important consideration—are insured through the use of a new tpye of motor which operates at a constant synchronous speed despite voltage, friction and temperature variations. *The use of synchronous motors for this purpose is a Sangamo development.*

No slippage or inoperative periods of appreciable length exist as the drive is positive and the pusher arm is reset almost instantaneously through the release of a spring wound up by the synchronous motor.

You can readily obtain the benefits derived from monthly maximum-demand readings as any Sangamo Type-H Watthour Meter may be easily converted into a combined watthour and demand meter by replacing the standard register with the Sangamo Maximum-demand Register. *Write for details.*

Sangamo Electric Company

Springfield, Illinois

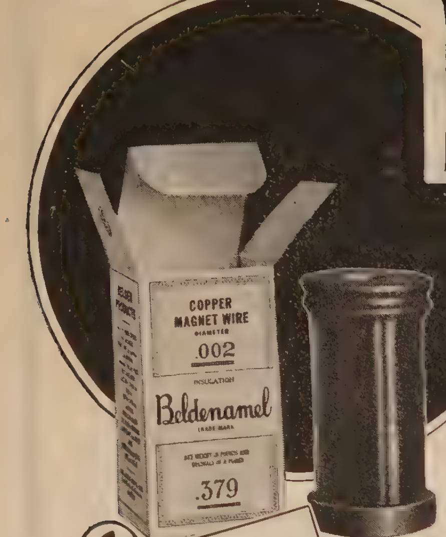
New York Chicago Birmingham San Francisco Los Angeles

SANGAMO METERS

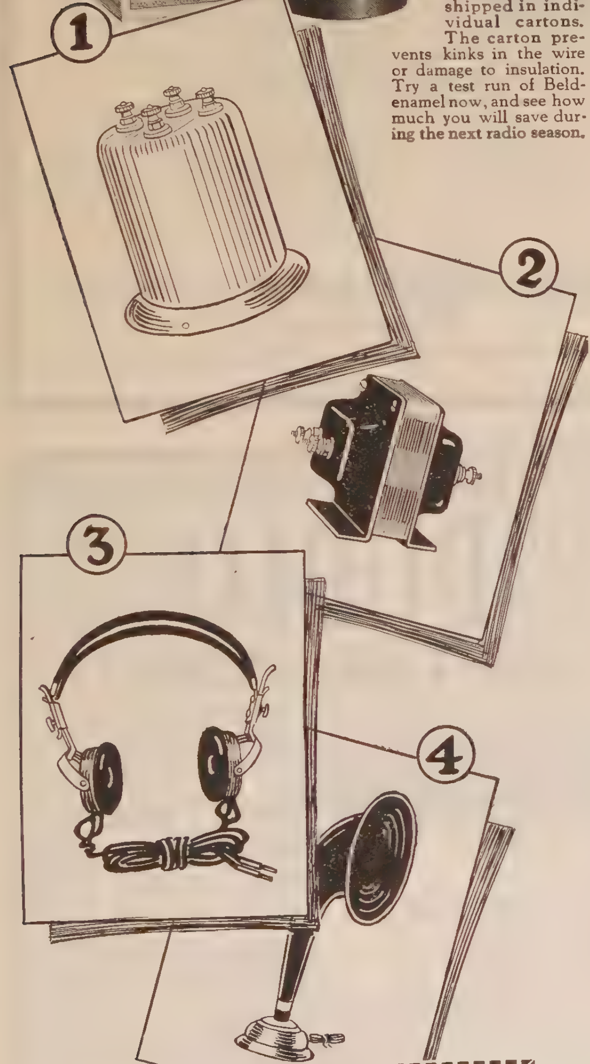
FOR EVERY ELECTRICAL NEED

6020-1

Beldenamel



BELDENAMEL, in sizes from No. 40 and finer, is shipped in individual cartons. The carton prevents kinks in the wire or damage to insulation. Try a test run of Beldenamel now, and see how much you will save during the next radio season.



The Ultimate Choice for Radio Devices

RADIO, the magic word of today, has brought new problems and new responsibilities. Radio buying is is done more carefully now, and a vast army of discriminating buyers has replaced the untrained, inexperienced enthusiasts of the first radio boom.

Radio manufacturers must build radio parts to higher standards than before, and so it is not strange that BELDENAMEL is now specified for radio devices of superfine quality.

1—Radio-Frequency Transformers

The uniform resistance and quality of Beldenamel insures radio frequency transformers of remarkably uniform impedance, so essential for efficient operation.

2—Audio-Frequency Transformers

The tremendous number of turns used in these transformers demands high-speed winding operations, uniform wire smoothly spooled, and insulation of high di-electric strength. The fact that Beldenamel is used in a large number of transformers of this type is evidence of its superiority for this application.

3—Radio Head Sets

A large number of turns in a small space, high-speed winding, and uniform impedance are the requirements of head-set manufacturers. Beldenamel is always the ultimate choice of the executive who watches his costs.

4—Radio Loud Speakers

Loud speakers are operated on higher B-battery voltages than head-phones. For this reason, Beldenamel, with its high di-electric test, insures a loud-speaker winding that survives severe service indefinitely.

Get in touch with us, now, for a sample lot of Beldenamel in any size from No. 5 to No. 46. Later in the season, when the demand for Beldenamel often exceeds the supply, we can give the best service to manufacturers who have anticipated their needs early in the season.

Belden Manufacturing Company

Electrical Wire, Cable and Cordage

General Office and Factory
2300 S. Western Avenue

Magnet Wire Department
4625 W. Van Buren Street

CHICAGO, ILLINOIS

Eastern office and warehouse
Metuchen, N. J.

Pacific Coast Representatives, Keeler-White Co
Los Angeles 211 S. San Pedro St. San Francisco 509 Mission St. Seattle Polson Bldg.

You are cordially invited to visit either one or both of our plants during the A. I. E. E. Convention at Chicago

Belden Manufacturing Company
4625 W. Van Buren Street, Chicago
We are anxious to know more about Beldenamel for

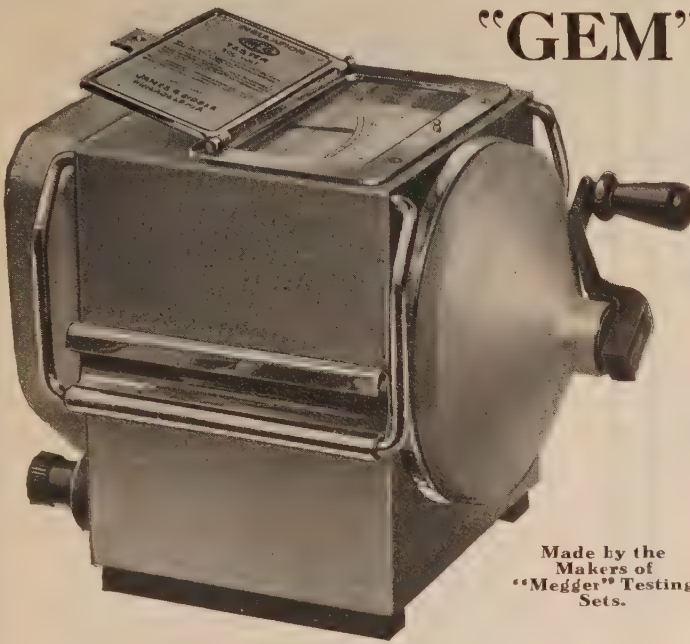
____

Please send us your recommendations and engineering data.

Name ____________________

Address ____________________ (J)

"GEM" Insulation Tester



Made by the Makers of "Megger" Testing Sets.

THE "MEG." (⅓ actual size.)

The scale, which is 3 in. long, reads directly from 0 to 100 megohms. The hand generator develops a steady potential of 500 volts direct current. To operate: connect leads to the two terminals, turn the crank and read.

The "Meg" stands 6¼ in. high and weighs 6¾ lbs

Price: $135 net, f. o. b. Philadelphia.

With the "Meg" anyone of ordinary intelligence can test, up to 100 megohms, the insulation resistance of generators, motors, transformers, cables, switchboards, wiring and other electrical apparatus.

Progressive engineers *everywhere* are obtaining reliable information by means of this simple "Meg" test which insures them against unexpected failure due to weakened insulation of electrical apparatus.

Among Central Station Operators and Construction Engineers the "Meg" is being used as a valuable supplement to our well-known "Megger" Testing Sets, which are built in ranges as high as 10,000 megohms. (1 megohm = 1 million ohms.)

And for private plants in Factories, Department Stores, Hotels, Office Buildings, etc. "Meg" testing is becoming common practice because it is a convenient method by which the plant engineer can detect "leaks" and "grounds" long before they become serious and can keep himself in close touch with the condition of his system.

Our new Pocket Manual 1060: *"Concerning Insulation Testing with special Reference to the Meg"* contains valuable data on insulation and how to test it. Write for copy.

JAMES G. BIDDLE

1211-13 Arch Street Philadelphia

NEW!

An addition to the Roller-Smith Bulletin file—just off the press—full of data on the application of small instruments to *Radio Receiving* and *Transmitting Sets* and *Broadcasting Stations.*

A new and very useful instrument is shown on page 5.

For your convenience

CLIP THIS SLIP

Request for Roller-Smith Bulletin AE-10.

Name ....

Company ....

Address ....

City .... State ....

An efficient pocket tool—

Furnished in handsome, sewed leather sheath.

NO need to do without Slide rule when away from your desk. The

5-inch
"POLYPHASE DUPLEX"
Slide Rule

fits your vest or coat pocket and is as handy as your pencil or fountain pen. Of patented K&E Duplex type *graduated on both sides.*

Folded Scales

reduce number of settings to a minimum. For example, squares, cubes and roots, are read directly, with one setting.

Saves so much time—costs so little that you cannot afford to be without one for your constant companion.

Price upon application

KEUFFEL & ESSER CO.

NEW YORK, 127 Fulton Street, General Office and Factories, HOBOKEN, N. J.

CHICAGO 516-20 S. Dearborn St. ST. LOUIS 817 Locust St. SAN FRANCISCO 30-34 Second St. MONTREAL 5 Notre Dame St. W.

Drawing Materials, Mathematical and Surveying Instruments, Measuring Tapes

[*Section removed to show construction*]

ROCKWOOD PAPER PULLEYS

1. Reduce slippage
2. Decrease belt tension
3. Transmit more power
4. Lower total cost of drive, due to narrower belts.

Whenever you buy a pulley for a motor, get a Rockwood Paper Pulley, the pulley that most every motor is equipped with when it leaves the factory. Rockwood is more than a pulley—*it is pulley service!* Order from your electrical dealer or direct from us.

THE ROCKWOOD MFG. COMPANY
1947 English Avenue INDIANAPOLIS, U.S.A.

MORSE SILENT CHAIN DRIVES

Low cost power transmission

Morse Silent Chain Drives transmit 98.6% efficiency. Sustain this efficiency over the life of the drive. This remarkable performance and very high efficiency mean greater power, and substantial power saving.

Morse Silent Chain Drives operate with maximum efficiency over short centers. This makes a very definite saving of valuable space possible.

Maintenance and up-keep are additional factors that enter into transmission costs. Morse Silent Chain cannot stretch, does not require treatment or constant dressing. In many instances the chain never has to be repaired in any way, shape, or form, the only attention required is timely lubrication.

MORSE CHAIN CO., ITHACA, N.Y.

There is a Morse Engineer near you

ATLANTA, GA.	DENVER, COLO.	PHILADELPHIA, PA.
BALTIMORE, MD.	DETROIT, MICH.	PITTSBURGH, PA.
BOSTON, MASS.	KANSAS CITY, MO.	SAN FRANCISCO, CAL.
CHARLOTTE, N. C.	NEW YORK CITY	ST. LOUIS, MO.
CHICAGO, ILL.	MINNEAPOLIS, MINN.	TORONTO, Ont., Can.
CLEVELAND, OHIO	MONTREAL, Que., Can.	WINNIPEG, Man., Can.

2118-30

THE ROWAN A.C. STARTING SWITCH

PUSH BUTTON OPERATED
OIL IMMERSED

FOR STARTING AND STOPPING SMALL SQUIRREL CAGE MOTORS THAT CAN BE THROWN ACROSS THE LINE

ROWAN CONTROL
THE ROWAN CONTROLLER CO., BALTIMORE, MD.

CROCKER-WHEELER

PIONEER MOTOR MANUFACTURERS
Established 1888

May 17, 1860
A milestone in electrical history

1860—a year of great moment for the world and industry: Planté—and the lead storage battery; Reis—and the telephone.

And on May 17, 1860, Schuyler Skaats Wheeler was born—engineer, manufacturer, author, inventor. To the brilliant mind and almost tireless energy of this electrical pioneer, can be traced a score of outstanding developments.

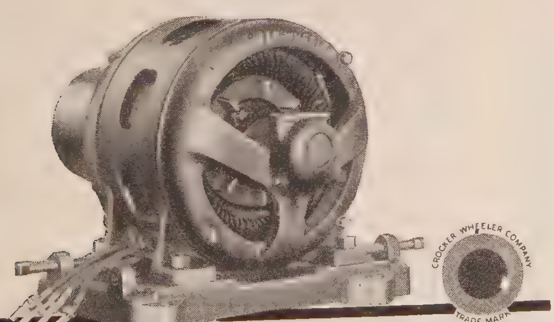
Among the many inventions of Dr. Wheeler may be named the electric fire engine, series-multiple motor control, and the paralleling of dynamos. In 1904, he received the John Scott medal of the Franklin Institute for inventing the electric fan.

For the important role it has played in the electric motor industry, the Crocker-Wheeler Company is immeasurably indebted to the genius of this remarkable man,—one of its founders and, until his death on April 20, 1923, its president.

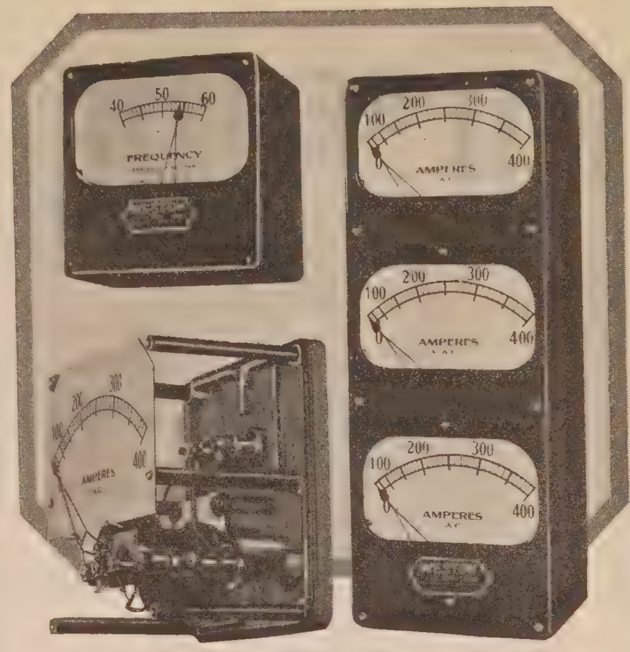
CROCKER - WHEELER COMPANY
AMPERE NEW JERSEY

BALTIMORE, BIRMINGHAM, BOSTON, BUFFALO, CHICAGO, CLEVELAND, DETROIT, NEW HAVEN, NEW YORK, PHILADELPHIA, PITTSBURGH, SAN FRANCISCO

Foreign Distributor: International Western Electric Co.



MOTORS & GENERATORS



Have You Specified Weston Rectangular Instruments Yet?

To the designer who faces immediate problems concerning densely settled communities or to the designer who is building with an eye to future needs, Weston instruments offer a real opportunity for better and less expensive switchboards. Here is a group of new instruments made by America's pioneer instrument maker—whose instruments have earned a reputation with engineers the world over as the best obtainable. This new size, 5¾ in. wide, 6 in. high, and 4¼ in. deep, is one that has received commendation everywhere. With these instruments, space requirements are radically reduced—in some cases by nearly one-half. Thus they allow more room for other devices while they cut down the space occupied by instruments. Mounting is standardized. Instant readings are assured by wide scale openings.

These new instruments have every advantage that is possible and are neat and compact. The new group is complete. It includes Alternating Current Ammeters, Voltmeters, Wattmeters, Frequency Meters, Power Factor Meters and Triplex Ammeters, and Direct Current Voltmeters and Ammeters.

These instruments are of vital importance to all engineers and switchboard designers.

Full information is contained in Bulletin 1504. Write for your copy today.

Weston Electrical Instrument Co.
48 Weston Ave., Newark, N. J.

Please send us Bulletin No. 1504 on the New Weston Rectangular Instruments.

Name...

Company...

Address..

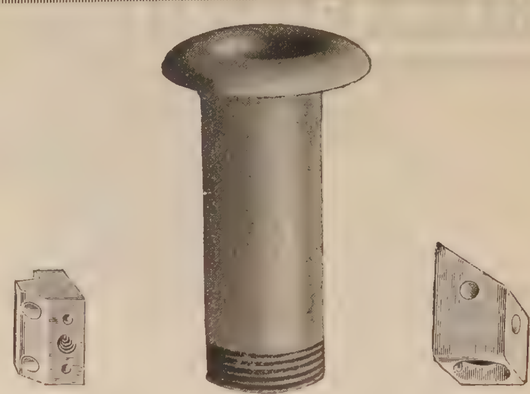
THE

U-RE-LITE

is so much better than a fused switch that it is in a class by itself

Handbook just off the press send for it

THE CUTTER CO.
Philadelphia



Insulators

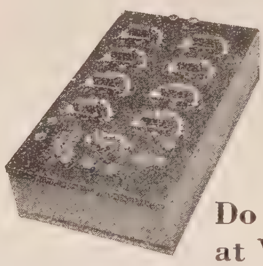
made of

Lava

Will best answer your requirements for a heat resistant insulation.

AMERICAN LAVA CORPORATION
27-67 Williamson St.
Chattanooga Tennessee
Manufacturers of Heat Resistant Insulators

IMPEDANCE BRIDGE



Do You *Guess* at Values of INDUCTANCE and CAPACITANCE?

Hardly necessary when it is so EASY to MEASURE, and measure accurately if you have a General Radio Co. Decade Bridge.

This bridge has three resistance arms, two of which consist of four-dial decades, with a range of 0.1 to 1111 ohms. The Ayrton-Perry Method of winding produces units, the resistances of which are nearly independent of frequency.

Mounted in a polished walnut cabinet, fitted with a copper shield to protect against outside electrostatic fields.

PRICE $125.

For use with this bridge—
Standards of Inductance
Standards of Capacitance
Standards of Resistance

All fully described in Bulletin 404-E sent free on request.

GENERAL RADIO CO.
Manufacturers of
RADIO AND ELECTRICAL LABORATORY APPARATUS
Massachusetts Avenue and Windsor Street
CAMBRIDGE 39 MASSACHUSETTS

5300

MARINE RULES

Recommended Practise for Electrical Installations on Shipboard

THE Marine Rules have been drawn up to serve as a guide for the equipment of merchant ships with electrical apparatus for lighting, signaling, communication and power, but not including propulsion. They indicate what is considered the best engineering practise with reference to safety of the personnel and of the ship itself, as well as reliability and durability of the apparatus. These rules are intended to supplement the STANDARDS of the A. I. E. E., which should be followed wherever applicable.

Linen covered, 97 pp., price, $1.00 per copy, with discount of 25% to members of the A. I. E. E., dealers, and purchasers of ten or more copies.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 West 39th Street, New York

Classified Advertiser's Index for Buyers

Manufacturers and agents for machinery and supplies used in the electrical and allied industries.

Note: For reference to the advertisements see the Alphabetical List of Advertisers on page 64.

AIR COMPRESSORS
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities

AIR WASHERS
Spray Engineering Co., Boston
Sturtevant Company, B. F., Boston

AMMETER COMPENSATING COILS
Minerallac Electric Co., Chicago

AMMETERS, VOLTMETERS
(See INSTRUMENTS, ELECTRICAL)

BATTERY CHARGING APPARATUS
Cutler-Hammer Mfg. Co., Milwaukee
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

BEARINGS, BALL
New Departure Mfg. Co., The, Bristol, Conn.
Norma Co. of America, L. I. City, N. Y.
S K F Industries, New York
Strom Ball Bearing Mfg. Co., Chicago

BOOKS, TECHNICAL
Wiley & Sons, Inc., John, New York

BOXES, FUSE
General Electric Co., Schenectady, N. Y.
Metropolitan Device Corp., Brooklyn, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

BOXES, JUNCTION
G & W Elec. Specialty Co., Chicago
Metropolitan Device Corp., Brooklyn, N. Y.
Standard Underground Cable Co., Pittsburgh

BRAKES, CAR
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
General Electric Co., Schenectady, N. Y.

BRUSHES, COMMUTATOR
Carbon
Morganite Brush Co., Inc., New York
National Carbon Co., Inc., Cleveland, O.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Copper Graphite
Morganite Brush Co., Inc., New York
National Carbon Co., Inc., Cleveland, O.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

BUS BAR FITTINGS
Burndy Engineering Co., New York
Champion Switch Co., New York
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CABLE ACCESSORIES
Dossert & Co., New York
Electrical Develop. & Machine Co., Phila.
G & W Electric Specialty Co., Chicago, Ill.
General Electric Co., Schenectady, N. Y.
Minerallac Electric Co., Chicago
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

CABLES
(See WIRES AND CABLES)

CABLEWAYS
Roebling's Sons Co., John A., Trenton, N. J.

CAMBRIC, VARNISHED
Belden Mfg. Co., Chicago
Irvington Varnish & Ins. Co., Irvington, N. J.

CARBON BRUSHES
(See BRUSHES COMMUTATOR)

CHAINS, POWER TRANSMISSION
Morse Chain Co., Ithaca, N. Y.

CIRCUIT BREAKERS
Automatic Reclosing Circuit Breaker Co., Columbus, O.
Condit Electrical Mfg. Co., S. Boston, Mass.
Cutter Co., The, Philadelphia, Pa.
General Electric Co., Schenectady, N. Y.
Roller-Smith Co., New York
Sundh Electric Co., Newark, N. J.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CLEAT TYPE INSULATORS
Electrical Develop. & Machine Co., Phila.

CLUTCHES, MAGNETIC
Cutler-Hammer Mfg. Co., Milwaukee

COILS, CHOKE
Champion Switch Co., New York
General Electric Co., Schenectady, N. Y.
Railway & Ind. Engg. Co., Greensburg, Pa.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

COILS, MAGNET
Acme Wire Co., New Haven, Conn.
Belden Mfg. Co., Chicago, Ill.
Dudlo Mfg. Co., Ft. Wayne, Ind.
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

COMPARTMENT DOORS
Electrical Develop. & Machine Co., Phila.

CONDENSATION PRODUCTS
Bakelite Corporation, New York
Condensite Co. of America, Bloomfield, N. J.
General Bakelite Co., New York
Redmanol Chemical Products Co., Chicago

CONDENSERS
Steam
Allis-Chalmers Mfg. Co., Milwaukee
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Radio
General Instrument Corp., New York
General Radio Co., Cambridge, Mass.

CONDUIT, UNDERGROUND FIBRE
Western Electric Co., All Principal Cities

CONNECTORS, SOLDERLESS
Dossert & Co., New York
Frankel Connector Co., Inc., New York
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONNECTORS AND TERMINALS
Belden Mfg. Co., Chicago
Dossert & Co., New York
G & W Electric Specialty Co., Chicago, Ill.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONTACTS, TUNGSTEN
Fansteel Products Co., Inc., North Chicago, Ill.
General Electric Co., Schenectady, N. Y.

CONTROLLERS
Cutler-Hammer Mfg. Co., Milwaukee
General Electric Co., Schenectady, N. Y.
Rowan Controller Co., Baltimore
Sundh Electric Co., Newark, N. J.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONVERTERS
Allis-Chalmers Mfg. Co., Milwaukee
Northwestern Electric Co., Chicago
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

COOLING PONDS
Spray Engineering Co., Boston

COPPER CLAD WIRE
Belden Mfg. Co., Chicago
Copperweld Steel Co., Rankin, Pa.
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

CUT-OUTS
Condit Electrical Mfg. Co., S. Boston, Mass.
General Electric Co., Schenectady, N. Y.
G & W Electric Specialty Co., Chicago
Metropolitan Device Corp., Brooklyn, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

DRAWING MATERIALS
Keuffel & Esser Company, Hoboken, N. J.

DYNAMOS
(See GENERATORS AND MOTORS

ELECTRIFICATION SUPPLIES, STEAM ROAD
General Electric Co., Schenectady, N. Y.
Ohio Brass Co., Mansfield, Ohio
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

ENGINEERS, CONSULTING AND CONTRACTING
(See PROFESSIONAL ENGINEERING DIRECTORY)

ENGINES
Gas & Gasoline
Allis-Chalmers Mfg. Co., Milwaukee
Oil
Allis-Chalmers Mfg. Co., Milwaukee
Steam
Allis-Chalmers Mfg. Co., Milwaukee

FANS, MOTOR
Century Electric Co., St. Louis
General Electric Co., Schenectady, N. Y.
Star Electric Motor Co., Newark, N. J.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

FARM LIGHTING GENERATORS
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

FIBRE
Belden Mfg. Co., Chicago
National Vulcanized Fibre Co., Wilmington, Del.

FURNACES, ELECTRIC
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

FUSES
Enclosed Refillable
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Enclosed Non-Refillable
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities
Open Link
General Electric Co., Schenectady, N. Y.
Metropolitan Device Corp., Brooklyn, N. Y.
Western Electric Co., All Principal Cities
High Tension
Metropolitan Device Corp., Brooklyn, N. Y.
Railway & Industrial Engg. Co., Greensburg, Pa.
Western Electric Co., All Principal Cities

GEARS, FIBRE
General Electric Co., Schenectady, N. Y.
National Vulcanized Fibre Co., Wilmington, Del.

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Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Century Electric Co., St. Louis, Mo.
Crocker-Wheeler Co., Ampere, N. J.
Electro-Dynamic Co., Bayonne, N. J.
General Electric Co., Schenectady, N. Y.
Northwestern Electric Co., Chicago
Star Electric Motor Co., Newark, N. J.
Sturtevant Company, B. F., Boston, Mass.
Wagner Electric Corp., St. Louis
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

GENERATING STATION EQUIPMENT
Allis-Chalmers Mfg. Co., Milwaukee
Electrical Develop. & Machine Co., Phila.
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

GROUND RODS
Copperweld Steel Co., Rankin, Pa.
Western Electric Co., All Principal Cities

HEADLIGHTS
Ohio Brass Co., Mansfield, O.

HEATERS, INDUSTRIAL
Cutler-Hammer Mfg. Co., Milwaukee
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

INDICATORS, LOAD
Dean Ltd., Payne, Stamford, Conn.

INDICATORS, SPEED
Biddle, James G., Philadelphia
Roller-Smith Co., New York

INSTRUMENTS, ELECTRICAL
Graphic
Biddle, James G., Philadelphia
Bristol Co., The, Waterbury, Conn.
Ferranti, Ltd., London, Eng.
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Indicating
Ferranti, Ltd., London, Eng.
General Electric Co., Schenectady, N. Y.
Roller-Smith Co., New York
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Weston Elec. Inst. Co., Newark, N. J.
Integrating
Biddle, James G., Philadelphia
Duncan Elec. Mfg. Co., Lafayette, Ind.
Ferranti, Ltd., London, Eng.
General Electric Co., Schenectady, N. Y.
Roller-Smith Co., New York
Sangamo Elec. Co., Springfield, Ill.
States Co., The, Hartford, Conn.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Radio
Acme Apparatus Co. Cambridge Mass.
General Instrument Corp., New York
General Radio Co. Cambridge, Mass.
Repairing and Testing
Electrical Testing Laboratories, New York
Scientific, Laboratory, Testing
Biddle, James G., Philadelphia
General Electric Co., Schenectady, N. Y.
Leeds & Northrup Co., Philadelphia
Metropolitan Device Corp., Brooklyn, N. Y.
Roller-Smith Co., New York
States Co., The, Hartford, Conn.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Weston Elec. Inst. Co., Newark, N. J.
Telegraph
Western Electric Co., All Principal Cities

Classified Advertiser's Index for Buyers—*Continued*

INSULATING MATERIALS

Cloth

Irvington Varnish & Ins. Co., Irvington, N. J.
Minerallac Electric Co., Chicago
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Composition

American Lava Corp., Chattanooga, Tenn.
Bakelite Corporation, New York
Belden Mfg. Co., Chicago
Condensite Co. of America, Bloomfield, N. J.
Cutler-Hammer Mfg. Co., Milwaukee
General Bakelite Co., New York
Redmanol Chemical Products Co., Chicago
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Compounds

Minerallac Electric Co., Chicago
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

Fibre

National Vulcanized Fibre Co., Wilmington, Del.

Lava

American Lava Corp., Chattanooga, Tenn.

Mica

New England Mica Co., Waltham, Mass.

Paper

Irvington Varnish & Ins. Co., Irvington, N. J.

Silk

Irvington Varnish & Ins. Co., Irvington, N. J.

Tape

Belden Mfg. Co., Chicago
Minerallac Electric Co., Chicago
Okonite Co., The, New York
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Varnishes

General Electric Co., Schenectady, N. Y.
Irvington Varnish & Ins. Co., Irvington, N. J.
Minerallac Electric Co., Chicago

INSULATORS, HIGH TENSION

Composition

General Electric Co., Schenectady, N. Y.

Glass

Hemingray Glass Co., Muncie, Ind.

Porcelain

General Electric Co., Schenectady, N. Y.
Illinois Elec. Porcelain Co., Macomb, Ill.
Jeffrey-Dewitt Insulator Co., Kenova, W. Va.
Lapp Insulator Co., Inc., LeRoy, N. Y.
Locke Insulator Corp., Victor, N. Y.
Ohio Brass Co., Mansfield, O.
Thomas & Sons Co., R., East Liverpool, O.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

INSULATORS, TELEPHONE & TELEGRAPH
Hemingray Glass Co., Muncie, Ind.
Western Electric Co., All Principal Cities

LAMP GUARDS
Western Electric Co., All Principal Cities

LAVA
American Lava Corp., Chattanooga, Tenn.

LIGHTNING ARRESTERS
General Electric Co., Schenectady, N. Y.
Railway & Industrial Engg. Co., Greensburg, Pa.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

LOCOMOTIVES, ELECTRIC
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

MANGANIN
Baker & Co., Newark, N. J

METERS, ELECTRICAL
(See INSTRUMENTS, ELECTRICAL)

METER TESTERS
States Co., The, Hartford, Conn.

MICA
New England Mica Co., Waltham, Mass.

MOLDED INSULATION
Bakelite Corporation, New York
Belden Mfg. Co., Chicago
Condensite Co. of America, Bloomfield, N. J.
Cutler-Hammer Mfg. Co., Milwaukee
General Bakelite Co., New York
Redmanol Chemical Products Co., Chicago
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

MOLYBDENUM
Fansteel Products Co., Inc., North Chicago, Ill.

MOTORS
(See GENERATORS AND MOTORS)

OIL SEPARATORS & PURIFIERS
Sharples Specialty Co., The, Philadelphia

PANEL BOARDS
(See SWITCHBOARDS)

PATENT ATTORNEYS
(See PROFESSIONAL ENGINEERING DIRECTORY)

PHASE MODIFYING APPARATUS
States Co., The, Hartford, Conn.

PLATINUM
Baker & Co., Newark, N. J.

PLUGS
Cutler-Hammer Mfg. Co., Milwaukee
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

POLES, STEEL
Pacific Coast Steel Co., San Francisco, Calif.
Western Electric Co., All Principal Cities

POLES—TIES, WOOD
Page & Hill Co., Minneapolis, Minn.
Texas Creosoting Co., Orange, Texas
Western Electric Co., All Principal Cities

POTHEADS
G & W Electric Specialty Co., Chicago
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

PROTECTIVE DEVICES
Metropolitan Device Corp., Brooklyn, N. Y.
Western Electric Co., All Principal Cities

PULLEYS, PAPER
Rockwood Mfg. Co., The, Indianapolis

PUMPS
Allis-Chalmers Mfg. Co., Milwaukee
Goulds Mfg. Co., Seneca Falls, N. Y.

PUMPS, SPIRAL
Cramp & Sons Ship & Engine Bldg. Co., The, Wm., Philadelphia

PYROMETERS
Leeds & Northrup Co., Philadelphia

RADIO APPARATUS
General Electric Co., Schenectady, N. Y.
General Radio Co., Cambridge, Mass.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

RADIO LABORATORY APPARATUS
Acme Apparatus Co., Cambridge, Mass.
General Radio Co., Cambridge, Mass.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

RAILWAY SUPPLIES, ELECTRIC
General Electric Co., Schenectady, N. Y.
Ohio Brass Co., Mansfield, O.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

REACTORS
Metropolitan Device Corp., Brooklyn, N. Y.

RECTIFIERS
General Electric Co., Schenectady, N. Y.
Wagner Electric Corp., St. Louis
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

REGULATORS, VOLTAGE
General Electric Co., Schenectady, N. Y.
States Co., The, Hartford, Conn.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg Co., E. Pittsburgh

RESISTANCE ELEMENTS
Cutler-Hammer Mfg. Co., Milwaukee
General Electric Co., Schenectady, N. Y.

RHEOSTATS
Biddle, James G., Philadelphia, Pa.
Cutler-Hammer Mfg. Co., Milwaukee
General Electric Co., Schenectady, N. Y.
Sundh Electric Co., Newark, N. J.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

ROPE, WIRE
Roebling's Sons Co., John A., Trenton, N. J.

SEARCHLIGHTS
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SOCKETS AND RECEPTACLES
Cutler-Hammer Mfg. Co., Milwaukee
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SOLENOIDS
Acme Wire Co., New Haven, Conn.
Belden Mfg. Co., Chicago
Cutler-Hammer Mfg. Co., Milwaukee
Dudlo Mfg. Co., Ft. Wayne, Ind.
General Electric Co., Schenectady, N. Y.
Sundh Electric Co., Newark, N. J.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

STARTERS, MOTOR
Automatic Reclosing Circuit Breaker Co., Columbus, O.
Condit Electrical Mfg. Co., So. Boston, Mass.
Cutler-Hammer Mfg. Co., Milwaukee
General Electric Co., Schenectady
Rowan Controller Co., Baltimore, Md.
Sundh Electric Co., Newark, N. J.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

STOKERS, MECHANICAL
Sturtevant Company, B. F., Boston, Mass.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SUB-STATIONS
General Electric Co., Schenectady, N. Y.
Railway & Industrial Engg. Co., Greensburg, Pa.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SWITCHBOARDS
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Condit Electrical Mfg. Co., So. Boston, Mass.
General Electric Co., Schenectady, N. Y.
Metropolitan Device Corp., Brooklyn, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SWITCHES *Automatic Time*
Ferranti, Ltd., London, Eng.
General Electric Co , Schenectady, N. Y.
Minerallac Electric Co., Chicago
Sundh Electric Co., Newark, N. J.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Disconnecting

Champion Switch Co., Buffalo, N. Y.
Condit Electrical Mfg. Co., So. Boston
General Electric Co., Schenectady, N. Y.
K-P-F Electric Co., San Francisco
Railway & Ind. Engg. Co., Greensburg, Pa.

Fuse

General Electric Co., Schenectady, N Y.
Metropolitan Device Corp., Brooklyn, N. Y.

Knife

Condit Electrical Mfg. Co., So. Boston
Cutter Co., The, Philadelphia, Pa.
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Oil

Condit Electrical Mfg. Co., So. Boston
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Remote Control

Condit Electrical Mfg. Co., So. Boston
Cutler-Hammer Mfg. Co., Milwaukee
Dean Ltd., Payne, Stamford, Conn.
General Electric Co., Schenectady, N. Y.
Railway & Ind. Engg. Co., Greensburg, Pa.
Rowan Controller Co., Baltimore
Sundh Electric Co., Newark, N. J.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

TACHOMETERS
Biddle, James G., Philadelphia

TANTALUM
Fansteel Products Co., Inc., North Chicago, Ill.

TELEGRAPH APPARATUS
Western Electric Co., All Principal Cities

TELEPHONE EQUIPMENT
Western Electric Co., All Principal Cities

TESTING LABORATORIES
Electrical Testing Labs., New York

TOWERS, TRANSMISSION
Pacific Coast Steel Co., San Francisco, Calif.
Western Electric Co., All Principal Cities

TRANSFORMERS
Acme Apparatus Co., Cambridge, Mass.
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
American Transformer Co., Newark, N. J.
Duncan Elec. Mfg. Co., Lafayette, Ind.
Ferranti, Ltd., London, Eng.
General Electric Co., Schenectady, N. Y.
Kuhlman Electric Co., Bay City, Mich.
Moloney Electric Co., St. Louis
Packard Electric Co., The, Warren, O.
Pittsburgh Transformer Co., Pittsburgh
Wagner Electric Corp., St. Louis
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Factory

American Transformer Co., Newark, N. J.
Kuhlman Electric Co., Bay City, Mich.
Moloney Electric Co., St. Louis, Mo.
Packard Electric Co., The, Warren, O.
Pittsburgh Transformer Co., Pittsburgh
Wagner Electric Corp., St. Louis
Western Electric Co., All Principal Cities

Furnace

Allis-Chalmers Mfg. Co., Milwaukee
American Transformer Co., Newark, N. J.
Moloney Electric Co., St. Louis
Packard Electric Co., The, Warren, O.
Pittsburgh Transformer Co., Pittsburgh

Metering

American Transformer Co., Newark, N. J.
Ferranti, Ltd., London, Eng.
Packard Electric Co., The, Warren, O.
Pittsburgh Transformer Co., Pittsburgh, Pa.

Mill Type

Pittsburgh Transformer Co., Pittsburgh

Radio

Acme Apparatus Co., Cambridge, Mass.
American Transformer Co., Newark, N. J.

Street Lighting

Kuhlman Electric Co., Bay City, Mich.
Packard Electric Co., The, Warren, O.
Western Electric Co., All Principal Cities

Classified Advertiser's Index for Buyers—*Continued*

ALPHABETICAL LIST OF ADVERTISERS

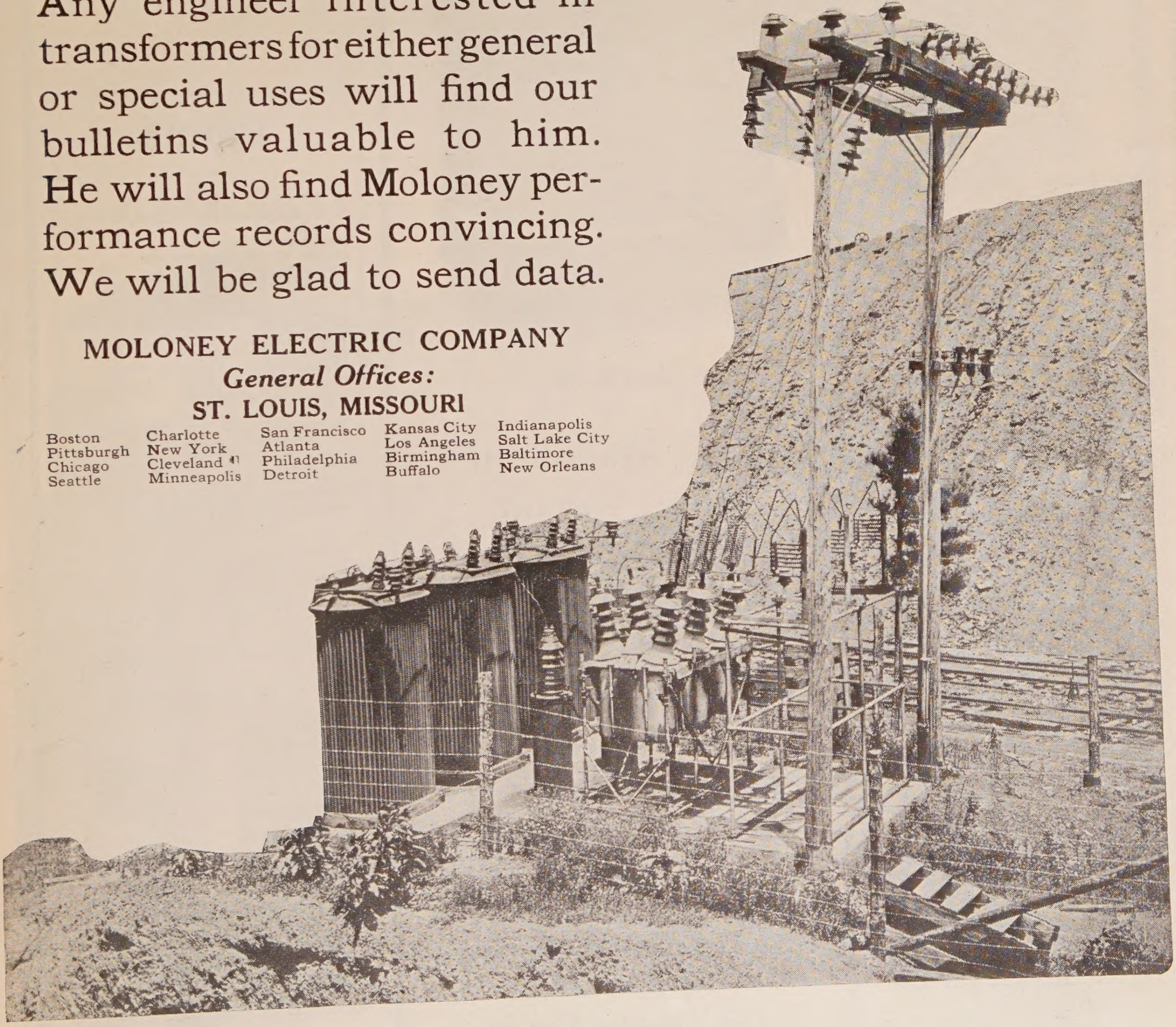
(For classified list of Advertisers see pages 58, 60 and 62)

Moloney

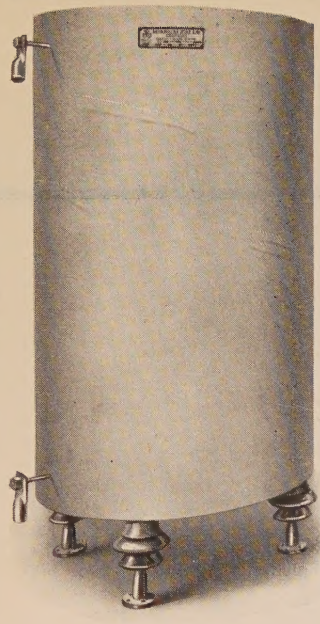
Users of these Transformer
of performance is born

Continuous and consistent high quality of performance, the utmost in satisfactory service, is the usual user's experience with Moloney Transformers. Hundreds of Moloney installations, perhaps several near you, demonstrate the quality of Moloney products every day.

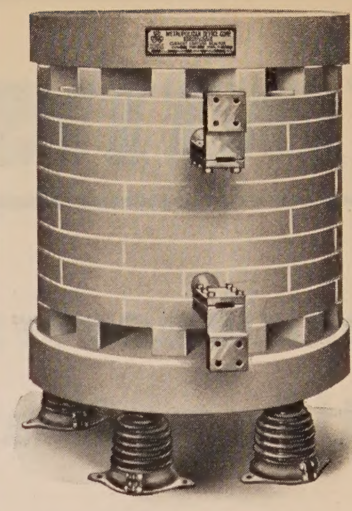
Exceptional performance is the direct result of the fine engineering, the honest workmanship, the high-grade ma-



Metropolitan
Current Limiting
Reactors



Outdoor Service



Indoor Service
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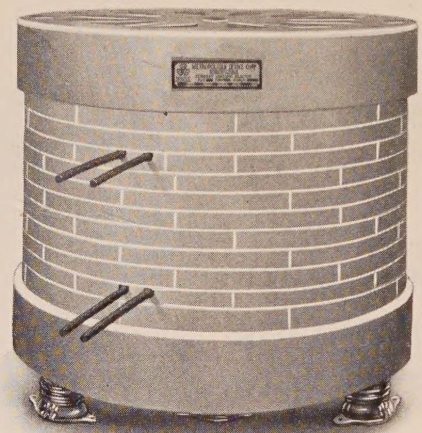


Indoor Service

USERS

Boston Edison Company
Bronx Gas Electric Co.
Brooklyn Rapid Transit Co.
Calgary Municipal Electric Co.
Canadian Niagara Falls Power Co.
Cataluna Power Co.
Chicago, Lake Shore & South Bend R. R.
Cohoes Light & Power Corp.
Commonwealth Edison Co.
Consolidated Gas & Electric Co.
Dayton & Power Light Co.
Detroit Edison Company
East Hampton Gas Co.
Edison Electric Illuminating Co.
El Paso Power & Railroad Co.
French General Electric Co.
Hydro Electric Power Commission
Havana Elec. Ry., Lt. & Pwr. Co.
Interborough Rapid Transit Co.
Joyce Gridland Railroad Co.
Municipal Gas Co.
New York Edison Company

USERS

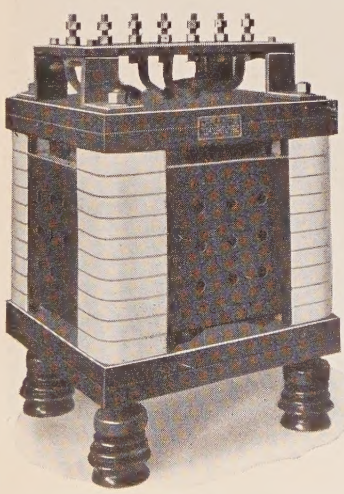
N. Y., N. H. & H. R. R. Co.
N. Y. & Queens Elec. Light & Pwr. Co.
Potomac Electric Co.
Public Works Department
Public Service Electric Co.
Shawinigan Hydro Elec. Power Co.
Tennessee Power Co.
Toledo R. R. & Light Co.
Toronto Power Co.
Turners Falls Power Co.
United Electric Lighting Co.
United Electric Light & Power Co.
Union Gas & Electric Co., Cincinnati
Union Electric Lt. & Pwr. Co., St. Louis
Utica Gas & Electric Co.
Victoria Falls & Transvaal P. Co.
Warren & Co.
Westchester Lighting Co.
Youngstown Sheet & Tube Co.

Give Maximum
Short Circuit
Protection
and
Highest All-Year
Efficiencies

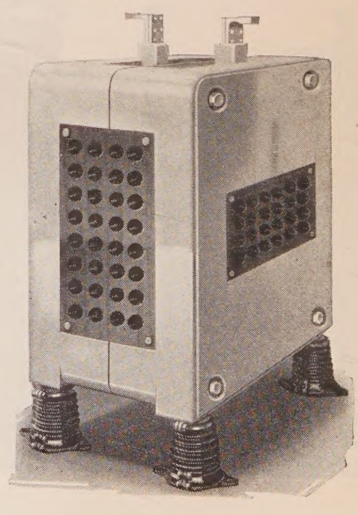
In daily use upon the greatest generating and distribution systems.

NONE MORE RELIABLE

Metropolitan Device Corporation
1250 Atlantic Avenue
Brooklyn New York



Testing Reactor



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Porcelain Lined


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Multiple Unit Door Control
OKONITE Wire Used Exclusively
Every precaution has been taken to insure the safety of the passengers and the reliability of operation.
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Ten Car Train Equipped with Multiple unit door Control
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